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WATER POLLUTION ABATEMENT PROGRAM
VILLAGE OF SAUGET, ILLINOIS

PHASE I REPORT 153960

MAY 15, 1972

Monsanto
Enviro-Chem
Systems Inc.

10 SOUTH RIVERSIDE PLAZA / CHICAGO, ILLINOIS 60606 / (312) 782-0372

May 24, 1972

Village of Sauget Board
of Trustees
2987 Monsanto Avenue
Sauget, Illinois 62206

Attention: The Honorable Paul Sauget
President of Board of Trustees

Gentlemen:

In accordance with the proposal dated 6/25/70 to the Village of Sauget, we submit herewith a report of our test work and preliminary process engineering design of a waste treatment facility for the Village wastewaters. The specific items contained herein include:

(1) Analyses of existing Village waste stream and individual waste sources.

(2) A description of laboratory and pilot plant studies.

(3) Recommendations for "in-battery limits" modifications in waste discharge.

(4) Preliminary process flow diagram.

(5) A preliminary plot plan.

(6) Forecast composition of influent and effluent from proposed treatment plant.

(7) Discussion of areas most likely to yield grants.

In fulfillment of our agreement Monsanto Enviro-Chem also submitted three previous reports entitled:

(1) Flow Measurement Report - December 22, 1970

(2) Report upon the Operation and Physical Condition of the Village of Sauget Primary Treatment Facility - January 4, 1971

(3) Preliminary Laboratory and In-plant Studies - July 20, 1971

After completion of the detailed process design, Monsanto Enviro-Chem will forward an addendum to this attached report which will contain:

(1) Capital cost estimate for proposed new treating facilities and modifications to primary plant and sewer modifications.

(2) Proposed rate schedule formula for determining fees to be paid by each contributing company.

Upon receipt of the above described addendum, Monsanto Enviro-Chem shall have completed all work authorized by the Village of Sauget in Paul Sauget's letters of July 6, 1970 and August 26, 1970 referring to the proposal dated May 28, 1970 and revised June 25, 1970.

Cordially,

MONSANTO ENVIRO-CHEM SYSTEMS, INC.

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INTRODUCTION

Monsanto Enviro-Chem began work on Phase I of the Village of Sauget Water Pollution Abatement Program in August of 1970.

On July 1, 1970 the State of Illinois Environmental Protection Act went into effect. Under this act the Environmental Protection Agency, the Pollution Control Board, and the Institute for Environmental Quality were established.

The water standards to be met at the time Enviro-Chem began the Phase I study were outlined in the Sewage and Industrial Waste Treatment Requirements and Effluent Criteria (Technical Release 20-22, Second Edition-1968 from the Illinois Sanitary Water Board) and the Water Quality Standards for Interstate Waters Between Illinois and Missouri (Rules and Regulations SWB-13-1967).

On December 4, 1970 the Pollution Control Board announced hearings to be held on proposed state-wide water effluent criteria.

On January 6, 1971 the Board unanimously adopted R70-3 which moved up the completion date for secondary treatment along the Mississippi River to December 31, 1973.

R70-8 (Effluent Criteria) (October 1970) was first revised on February 8, 1971 after three public hearings. Changes involved dilution water, more stringent metals criteria, phosphorous and nitrogen.

In #R71-14 on May 12, 1971 the Board adopted another more complete set of Proposed Water Quality Standards Revisions and Effluent Criteria.

On December 5, 1971 the Board published another revision to effluent criteria and the proposed final draft of Water Pollution Regulations on December 21, 1971.

During January and February of 1972 the Water Quality Standards and Effluent Criteria were adopted - 18 months after Enviro-Chem had begun the study to determine a scheme of treatment to solve the Village's wastewater problems.

Because of the many changes in the proposed criteria, both the Village of Sauget and Enviro-Chem have been required to expend additional time and money to arrive at a system to reduce the water pollution levels at Sauget. In August of 1971 the Village contracted Enviro-Chem to evaluate alternative wastewater collection and treatment systems because of the proposal requiring treatment of all water in combined sewers to meet proposed effluent criteria. Two reports were issued by Enviro-Chem, one on October 15, 1971 and the second on December 31, 1971.

During 1971 the Village presented testimony at Evanston on 3/26, at Carbondale on 6/30, at Peoria on 10/6, Sauget on 11/8, and Chicago on 12/15 describing the work that had been done by the Village and their consultants. This testimony included opinions on technical feasibility of certain criteria as well as capital cost and operating cost estimates.

Because of the delays caused by additional work required by changing criteria, the Phase I report is being issued in essentially complete form slightly over three months behind the schedule proposed in June of 1970.

OBJECTIVES

MONSANTO ENVIRO-CHEM SYSTEMS INC. agreed to provide to the Village of Sauget the following items in the course of studying the Village waste water problems:

1. Analysis of each contributing waste stream and of the combined streams as they are fed to the existing primary treating plant, showing all important contaminants and the range and variations in flow rates.

2. Proposed composition of the effluent stream from a new treating plant, showing residual amounts of all important contaminants.

3. A process flow diagram and description of how the existing treatment plant will be utilized.

4. A plot plan showing the arrangement of components and the amount of land required.

5. A complete technical report of laboratory and prototype plant studies including:

    a. a description of the equipment and operating plan
    b. batch treating rates
    c. effluent characteristics at various prototype plant detention times
    d. results of pretreatment studies
    e. frequency distribution analyses of important raw waste characteristics
    f. recommended plant design factors.

6. Recommendations for "in-battery limits" modifications by various contributing plants where these will result in better over-all economics.

7. Proposed rate schedule formula for determining fees to be paid by each contributing company.

8. Recommendations for areas most likely to yield federal grants and a description of procedures.

9. Capital cost estimate for proposed new treating facilities and modifications to primary plant and sewer modifications.

SUMMARY OF RESULTS

The following summary of results for the on-site pilot plant study and associated test program conducted for the Village of Sauget evaluate possible process alternatives and determine necessary design parameters. The first section of this summary will describe the results from the study pertaining to the recommended preliminary process design, the second section will deal with the process alternatives investigated but not recommended in the preliminary design.

Section One - Preliminary Process

A. Village Waste Flows Observed (June - August 1971)

Based on on-site observations at the Village treatment plant, the following data summerizes the waste flow rates, average peak and duration of peak:

1. The average waste flow is 18 MGD.

2. On approximately 86% of the 92 days of observation, flow peaking was less than 1/4 hour in duration and random.

3. On 14% of the 92 days of observation, flow peaking occurred for a duration of greater than 1/4 hour but less than six hours.

4. On 3% of the 92 days of observation, flow peaking of greater than 1/4 hour duration can be attributed to rainfall.

5. On 3% of the 92 days of observation, flow peaking of greater than 1/4 hour occurred randomly.

6. On 8% of the 92 days of observation, flow peaking of greater than 1/4 hour occurred between the hours 8 AM and 12 noon during the period of Monday through Friday.

7. Maximum peak flow observed during dry weather period was 32 MGD which was approximately 80% over the monthly average flow. The duration of this peak was 1/4 hour.

8. Maximum duration of a peak above the monthly average observed during the dry weather period was six hours. The flow was 24 MGD which was approximately 30% above the average flow.

9. Daily average flow was at a minimum on Sundays.

B. Storm Water Storage and Clarification

A system to collect "first flush" storm water for complete treatment and for clarification of excess storm flows was studied.

1. The storm water storage capacity, based on containing the "first flush" storm flow, is 800,000 gallons.

2. The excess storm flow clarification system design is based on an overflow rate of 2,000 gal/day-ft^2 and a maximum estimated sewer capacity of 128.5 cfs for the existing sewers.

C. Grit Chamber

An average volume of 260 cubic feet per day and a maximum of 520 cubic feet per day were determined from the volumes demucked and frequency of the demucking of the present facility.

D. Neutralization/Precipitation

Lime treatment will be necessary for reducing acidity, removal of heavy metals and suspended materials

1. The acidity of the present 1971 Village waste stream was determined by five methods. Of the widely diverging values, 250,000 to 275,000 pounds of acidity per day as $CaCO_3$ was determined to be the best representation of the waste lime requirements during pilot plant operations.

2. High calcium quicklime was chosen as the best neutralizing agent based on technical feasibility, availability, reaction time, cost and sludge characteristics.

3. Treatment of the raw waste with high calcium quicklime removed heavy metals to levels consistently less than the adopted state standards.

4. Treatment of the raw waste with high calcium quicklime does not remove a significant amount of the soluble BOD_5, COD, or color at high lime dosages greater than 1,000 mg/l.

5. Lime usage in the pilot plant was approximately twice the value expected from acidity measurements taken by the treatment plant with semi-continuous non-flow proportioned samples.

6. Possible errors in treatment plant measurements, precipitation of metals, scrubbing of CO_2 from the air, probable errors in lime usage measurements, and inerts as impurities in the lime purchased could account for about 50% or more of the increase lime usage observed in the pilot plant.

7. Average lime delivery capacity should be available to deliver 112,000 lbs CaO/day which is twice the amount required based on predicted acidity values of 100,000 lbs/day as $CaCO_3$ for 1974.

8. Maximum lime delivery capacity should be available to deliver 357,000 lbs CaO/day which is 1.5 times the amount required based on predicted maximum acidity values of 425,000 lbs/day as $CaCO_3$.

9. Maximum instantaneous lime delivery capacity will be 295 lbs CaO/min.

E. Coagulation and Flocculation

Suspended solids removal is not adequate without the addition of polyelectrolytes. Based on extensive batch testing of commercially available flocculating aids, Atlas 2A2 was found to produce the lowest effluent suspended solids. During pilot plant testing, Atlas 2A2 was applied at an average concentration of 0.5 mg/l producing an effluent suspended solids level of 37 mg/l without sludge recycle, and 42 mg/l with sludge recycle.

F. Clarifier Design

An overflow rate of 500 $gal/ft^2/day$ was selected based on engineering judgement. Tests indicated that at an effluent suspended solids concentration of less than 50 mg/l, the SS concentration was independent of overflow rate. Use of an overflow rate of 500 gpd/ft^2 will allow utilization of the existing clarifiers for a significant capital cost savings.

G. Sludge Handling

During pilot plant work, sludge generation rates were monitored and work was conducted to evaluate sludge conditioning, thickening, vacuum filtration, centrifugation and sludge disposal.

1. A solids balance was maintained on the pilot plant system exclusive of grit. The sludge generation was approximately 0.7 lbs sludge generated/lb CaO added.

2. Sludge solids coming into the system in the raw waste and removed will be approximately 20,000 lbs/day.

3. Atlas 105C, a sludge conditioning agent, showed low reduction (50%) in specific resistance to filtration at a dose rate of 14 lbs/ton sludge.

4. Thickening experiments indicated that thickening is not economically attractive for the 8% solids from the clarification step.

5. Eight per cent sludge can be concentrated to 30% by weight by vacuum filtration with the following conditions:

   Filter Media - Napped Cotton
   Filter Porosity-30 cfm at 0.5 in H_2O
   Loading - 2.0 lbs/ft^2-hr at 15" Hg - applied vacuum
   Filtrate Solids - 40 mg/l

6. With a feed solids concentration of 2% and a liquid retention time of approximately 1.5 minutes, 92% solids capture was achieved by centrifugation, with a cake solids concentration of 25 to 30% by weight. No chemicals were added for sludge conditioning.

7. Concentrated sludge solids, 25% or greater, should be disposed of by landfill.

H. Floating Debris, Visible Oil Scum

1. From 5 to 10 ft^3/day of floating debris should be removed daily in the trash racks.

2. From 500 to 700 ft^3/day of water and floating scum and oil should be removed from the system for decanting and disposal of scum.

I. Overall Performance of Chemical Treatment System

Based on pilot plant data, the expected performance of a chemical treatment system for the Village of Sauget waste (1971) contaminant loads), 1974 + flows have been summarized in the attached Table.

TABLE 1

SUMMARY OF
STATE OF ILLINOIS EFFLUENT
CRITERIA TO BE MET BY PROPOSED
CHEMICAL TREATMENT SYSTEM

Item	In Compliance	Out of Compliance
Settleable Solids	X	
Floating Debris	X	
Visible Oil	X	
Grease	X	
Scum	X	
Sludge Solids	X	
Color		X
Odor		X
Turbidity		X
Arsenic (Total)	X	
Barium (Total)	X	
Cadmium (Total)	X	
Chromium +6 (Total)	X	
Chromium +3 (Total)	X	
Copper (Total)	X	
Cyanide		X
Fluoride (Total)	X	
Iron (Total)	X	
Iron (Dissolved)	X	
Lead (Total)	X	
Manganese (Total)	X	
Mercury (Total)		X
Nickel (Total)	X	
Oil (Hexane Soluble or Equivalent)		
pH	X	
Phenols		X
Selenium (Total)	X	
Silver	X	
Zinc. (Total)	X	
Total Suspended Solids		X
Total Dissolved Solids		X
Bacteria		X?
BOD_5		X

Section Two - Other Process Options Evaluated

Several process options were evaluated during the on-site and pilot plant studies which were not recommended. The results of these investigations are summarized individually below.

A. Biological Treatment

1. Previous biological testing work done in 1959 treated a vastly different waste stream which contained a high amount of pure phenol.

2. Changes in the Village waste since 1959 have included an addition of more substituted aromatic compounds and other slow or difficult to degrade organics.

3. Inhibition to bioactivity was exhibited in the BOD_5 test of the raw waste.

4. Inhibition to bioactivity was exhibited on occasion in the BOD_5 test of the chemically treated waste.

5. Inhibition to bioactivity was exhibited on occasion in the BOD_5 test of the chemical and activated carbon treated effluent.

6. Batch treatability results indicated that some portions of the waste are degradable, but that the BOD loading was so low that a viable system was never attained.

7. A continuous feed Busch unit was used for a bench scale treatability study. The waste BOD_5 varied from 15 to 42 mg/l and the system was essentially starved because of the lack of food.

8. The pilot plant activated sludge system consisted of a 90 gallon aeration tank which was fed effluent from the chemical treatment system.

9. In an attempt to acclimate domestic activated sludge to the waste, milk was added as an additional substrate. The system did not respond favorably to the readily degradable waste as evidenced by the low VLMSS and low oxygen uptake rates. No higher forms, i.e. protozoa, were observed in the sludge after addition of the Sauget waste.

10. No color removal was noted in the pilot plant tests, bench scale test, nor in batch tests.

11. Phenols were removed to a level of approximately 1 mg/l in the bench scale unit.

12. Air stripping experiments indicated 38% and 21% COD removal for 18 and 22.5 hour aeration periods respectively.

13. A continuous feed aeration unit operated during pilot plant operations showed that COD removals could be as high as 50% with a retention time of 12 hours.

14. Chlorine is normally present in portions of the Village sewers in concentrations sufficient to cause substitution but not necessarily destruction of aromatics.

15. At times chlorine levels were high enough to destroy certain aromatics as indicated by a change in the waste color and measurement of free chlorine levels.

16. Chlorine levels in the chemical system effluent during the period of 5/12 to 5/22 were equal to or below 0.01 mg/l. This was the feed to the pilot plant activated sludge unit and was considered to be representative of the normal Cl_2 level.

17. The specific contaminant(s) which inhibited the biological system were not determined.

18. Equalization of the waste by feeding 24 hour composite samples to the bench unit did not allow maintenance of a viable system, thus indicating a lack of a readily biodegradable food source in sufficient amounts.

B. Activated Carbon

1. Preliminary isotherms and subsequent bench scale column testing indicated the Darco activated carbon is capable of removing color, phenols, and odor satisfactorily.

2. Pilot scale four-inch diameter multiple column testing and BDST data analysis yielded a loading factor of 8 lbs Darco carbon/1000 gallons treated for a 20 + MGD flow.

3. Short bed depth column experiments indicated superior adsorption kinetics for Darco and Calgon carbons relative to Witco and Nuchar carbons. At flow rates used for the small column experiments, the bed depths were approximately equal to the critical bed depth.

4. Activated carbon treatment - preceeded by a chemical treatment system and filtration - can not reduce the BOD_5 to the 20 mg/l level required by the adopted state criteria.

5. Testing of adsorption as a function of pH indicated that certain organics are removed more efficiently at a pH higher or lower that the pH of 8.5 from the chemical treatment system. Carbon treatment at a pH of 8.5 for color removal in the Monsanto waste is much less efficient than at other pH levels. Carbon treatment of the Midwest Rubber waste alone at a pH of 8.5 leaves a high BOD_5 remaining in solution. Carbon treatment of the Edwin Cooper waste alone at a pH of 8.5 leaves a high organic content remaining in solution and a high BOD_5 level.

6. Multiple regeneration experiments indicated decreasing adsorption efficiency with an increasing number of regenerations, due to the salt build up in the regenerated carbon.

7. Acid wash of the regenerated carbon appeared to restore its performance characteristics after regeneration.

8. Laboratory studies of regeneration furnace off gases indicated that the evolution of HCL and substantial amount of organics may be expected during regeneration, requiring proper air population abatement precautions to be included in the regeneration furnace.

9. Computer cost estimates were used to optimize the proposed system design and to determine cost sensitivity to waste organic content as indicated by COD.

   The cost for carbon adsorption (including sand filtration) for an 11.5 MGD plant would be approximately 4.5 million dollars capital and 3.6 million dollars total yearly operating cost (1971 dollars). This is based on a COD loading of 50,000 lbs/day.

C. Filtration

1. Effluent solids concentration of 25 mg/l or lower are obtained from multi media filtration of the clarified effluent with a bed comprised of 18 inches of 10x20 mesh coal, 9 inches of 20x40 mesh sand, and 3 inches of 40x80 mesh garnite. Optimum flow rate was three gal/min/ft^2 and a cycle time of 24 hours.

2. The filters did not operate successfully with clarification bypassed. Effluent solids breakthrough occurred to rapidly for practical operation.

D. Sulfide Precipitation

1. Sulfide precipitation is an added treatment step and did not provide an effluent which would have met the original proposed metals criteria, i.e. copper at 0.04 mg/l, total heavy metals at 2 mg/l.

2. Overall reductions of specific heavy metals after lime treatment to the pH of 8 to 8.5 was not adequate to justify further test work,

E. Chlorination or Disinfection

Data on total coliform indicate that disinfection of the present Sauget waste will not be necessary.

CONCLUSIONS

The conclusions are presented in the same format as the Summary of Results.

Section One - Preliminary Process

A. Plant Flows

1. Based on 1971 observations, flow peaking does not occur on any specific day or during any specific time period during a day.

2. Based on 1971 observations, peak flows during dry weather for short durations (approximately 1/4 hour) may exceed the average by as much as 80%.

3. Based on 1971 observations, peak flows during dry weather for periods greater than 1/2 hour will not exceed the average flow by more than 25%.

4. Based on 1974 prediciitions by the Village, maximum peak flows during dry weather periods will be about 50% above the average for a maximum duration of four hours.

5. With projected flow reductions, the magnitude of duration of expected flows relative to the average flow will increase. The predicted 1974 flow will govern plant design rather than the 1971 observations. Treatment plant design flow will be 11.5 MGD based on treatment of process wastes and "first flush" storm flows.

B. Storm Water Storage and Clarification

1. "First flush" treatment plus process surge capacity will require 800,000 gallons and 300,000 gallons respectively for 1974 + flows.

2. All storm water will receive at least clarification based on a calculated maximum sewer capacity of 128.5 cfs.

C. Grit Removal

1. To prevent grit build up in the system, a removal system should be installed before neutralization, flocculation and clarification.

2. Economics dictate that grit chambers should be above grade after the pumping station rather than in front of the existing station.

D. Neutralization/Precipitation

1. State effluent criteria for all metals except mercury can be consistantly met by chemical treatment of the Village waste with lime to a pH of between 8 and 8.5.

2. Treatment with lime followed by flocculation and sedimentation will not allow compliance with adopted criteria for color, odor, turbidity, BOD_5, cyanide, mercury, phenols, total suspended solids and total dissolved solids.

3. With changes in concentration of sulfate ions because of flow reductions dolomitic lime, as an alternative neutralizing agent, should be given careful consideration during the detailed process design. Dolomitic lime could reduce sludge volume and scale formation.

E. Coagulation & Flocculation

1. A coagulation and flocculation step will be required prior to clarification in order to achieve maximum effluent clarity and minimum suspended solids content.

2. Atlas 2A2 anionic polyelectrolyte was shown from extensive testing to produce an effluent of the highest quality.

F. Clarification

1. An overflow rate of 500 gal/day/ft^2 should be used for design of the clarifiers.

2. Clarifier sludge recycle to the head of the chemical treatment system does not appear to improve effluent quality.

3. Prediction of the exact suspended solids level from the clarifiers is impossible at this time because of proposed changes in the Village waste in 1974+. Suspended solids levels may not be below the 25 mg/l level.

G. Sludge Handling

1. Because of discrepancies between theoretical and actual lime requirements for neutralization and an unexplainably high content of $CaCO_3$ in the sludge, sludge handling capacity should be based on a generation rate of 0.7 pounds sludge per pound CaO used for a lime usage of 1.5 times the predicted acidity - 84,000 pounds CaO, approximately 59,000 pounds sludge per day.

2. Suspended solids requiring removal in the raw waste will be about 20,000 lbs/day.

3. Sludge concentration from the clarifier will be about 8% by weight and no gravity thickening operation will be required before final concentration.

4. Concentration of the clarifier sludge will be accomplished by vacuum filtration because of better solids capture and ease of operation.

5. No sludge conditioners will be required for the vacuum dewatering operation.

Section Two - Other Process Options Evaluated

A. Biological Treatment

1. Biological treatment of the present waste stream is not a technically sound method of reducing organic contamination.

2. Batch treatability results, bench scale continuous results and pilot plant results all indicate that the waste is not readily amenable to biological treatment.

3. Addition of a readily biodegradable substrate to the waste did not produce a viable biological system.

4. Very long retention times in a biological system would be required to degrade the organic constitutes in the waste if in fact a viable biological system could be maintained by supplemental substrate addition to the waste.

5. Waste inhibition can be attributed to both inorganic and organic constituents present.

6. The color bodies and phenols present in the waste were not removed to an adequate level in the biological experiments.

7. Air stripping allows significant reduction in waste COD and could cause a costly air pollution control problem.

8. Free chlorine levels in the feed to the biological test units were not responsible for system failures.

9. Chlorination of the waste in the sewers could increase resistance of certain organics to biodegradation.

10. Chlorine dumps would affect a biosystem if installed at Sauget because the same buffer capacity as was present before the pilot plant biosystem would not exist.

11. Because of the many organic contaminants and concentration fluctuations from day to day or from hour to hour, an extensive research program would be required using a synthesized waste to determine if removal at the source of specific contaminants would allow successful treatment biologically.

B. Activated Carbon Treatment

1. Activated carbon treatment of the present Village waste will not provide an effluent in compliance with the adopted BOD_5 criteria of 20 mg/l.

2. Activated carbon preceded by filtration is a technically feasible method for removal of phenol, color, odor, turbidity and suspended solids.

3. Activated carbon treatment of the total Village waste stream is not the most efficient or economical method for removal of many of the organic contaminants from Edwin Cooper, Midwest Rubber and Monsanto. These three companies contribute well over 90% of the organic waste load which is measured as BOD_5, phenol, color and odor.

4. Any decrease in the estimated carbon recovery would greatly increase yearly operating cost for an end of pipe carbon treatment system.

5. From the preliminary capital and operating cost estimates, pulsed bed contactors appear to have better overall economics compared to multiple fixed bed columns and should be considered if carbon treatment is evaluated at a later date. The accuracy of the pulsed bed estimates, however, is questionable because of the state of present technology.

C. Filtration

Filtration cannot be justified at this time because

1. Waste characteristics will change drastically and solids removal compared to pilot plant operations could be greatly improved.

2. If joint treatment with East St. Louis becomes a reality, then this unit operation would be unnecessary.

D. Disinfection

Disinfection cannot be justified at this time because pilot plant data indicated very low total coliform levels. The waste characteristics, however, will change drastically and the sterilizing effect of the waste may increase or decrease.

RECOMMENDATIONS

1. The Village of Sauget should proceed as planned on design and installation of a chemical treatment system. Preliminary design parameters for the recommended unit operations, a preliminary block flow diagram, and a preliminary plot plan are shown in Table 2 and Figures 1 and 2 .

2. The Village of Sauget should obtain from the various wastewater contributors within the Village, details of their plans for reducing those contaminants present in the chemical system effluent which will not be expected to be in compliance with the adopted state effluent criteria. Our recommendations for reductions by individual contributors are shown in Table 3 . Some of the recommended changes have already been planned such as major flow reductions and metals reductions.

3. The Village of Sauget should obtain from the various waste water contributors within the Village, details of any plans for flow reductions or changes in waste characteristics which would increase the severity of expected problems or produce new problems complying with the state effluent criteria. This information must be provided prior to the design of the chemical system.

4. As requested by the Southwestern Illinois Metropolitan Area Planning Commission, the Village of Sauget should continue consideration of joint treatment with the City of East St. Louis if reductions in those contaminants which would be out of compliance in the chemical system effluent cannot be reduced adequately at the sources.

5. The Village should begin compiling the information and fulfilling requirements required for construction grant applications for fiscal year 1974.

RECOMMENDATIONS (continued)

6. If contaminant reduction at the source and/or joint treatment with East St. Louis are not technically or economically feasible, advanced waste treatment techniques such as activated carbon treatment should be reevaluated with practical contaminant reductions.

TABLE 2

RECOMMENDED UNIT OPERATIONS

1. Trash Screens
   Use existing screens - repairs necessary
   Type - Vertical wooden bars
   Number of Screens - 3
   Openings - 2 inches
   Type of Trash - Agglomerated rubber and residue, wood, rags, hoses
   Volume of Trash - 10 cubic feet/day, maximum
   Trash removal - Mechanical, manually activated
   Trash disposal - Landfill

2. Pumping Station
   Use existing station - modifications and repairs necessary
   Capacity to pump to treatment plant -
   maximum - 11.5 MGD, 8050 gpm, 18 cfs
   average - 8.75 MGD, 6120 gpm, 13.7 cfs
   Capacity to pump to storage lagoon or storm water clarifier
   maximum - 71 MGD, 49,600 gpm, 110.5 cfs

3. Storm Water Storage Lagoon

   Design Capacity: 800,000 gallons Storm
   300,000 gallons Peaks
   1,100,000 gallons Total

   Operating (Design): Water Depth = 10 feet
   Width = 141 feet) (mean dimensions
   Length = 160 feet)
   Freeboard = 3 feet

   Embankment Slopes: Interior: 3 horizontal to 1 vertical
   Exterior: 3 horizontal to 1 vertical

   Embankment Thickness: 8 feet at top, minimum

Embankment Height: 13 feet from bottom of lagoon

Top Interior Dimensions: Length = 178 feet
Width = 159 feet

Bottom Interior Dimensions: Length = 100 feet
Width = 81 feet

Total Basin Volume = 223,000 cubic feet

Liner: Impervious to water

Solids Removal: Front-end-loading bulldozer to landfill

Estimated Yearly Volume Processed: 66,000,000 gallons

Estimated Yearly Solids Retention: 1,330,000 gallons

Frequency of Cleaning: 4 times/year to maintain 75% operating capacity

Inlet: Baffled

Outlet: Float controlled with flexible arm; "Stop" mechanism to prevent sludge draw-off

4. Storm Water Clarifier

Purpose: To provide primary clarification to storm waters in excess of treatment plant design flow after storage of "First Flush"

Design Overflow Rate: 2000 gal./ft.^{2}-day, maximum

Weir Overflow Rate: 15,000 gal/lin.ft.-day, maximum

Design Flow Rate: 71.5 MGD, maximum

Surface Area (Working): 35,750 square feet

Working Depth: 12 feet

Freeboard: 3 feet

Embankment Slopes: Interior: 3 horizontal to 1 vertical
3 horizontal to 1 vertical

Embankment Thickness: 8 feet at top, minimum

Embankment Height: 15 feet from clarifier bottom

Total Basin Volume: 566,000 cubic feet

Basin Working Volume: 308,000 cubic feet

Liner: Impervious to water (ground water relief valves required to prevent damage to liner when drained.)

Scum Removal: Manually tiltable trough with drain to sump pump to central scum handling facility.

Estimated Average Volume
Processed: 40,000,000 gal./year
90,000,000 gal./year

Total Clarifier Working Volume = 2,300,000 gallons
(308,000 cubic feet)

Influent Suspended Solids = 100 mg/l average

Estim. % Solids Removal = 70%

Underflow Suspended Solids = 8%

Vol. Suspended Solids Retention = 40,000 gal/year aver. - 90,000 gal/year maximum

Demucking Frequency = One every 72 months (to maintain ~75% or more working capacity)

5. <u>Grit Chamber</u>

Type - rectangular
Number of Chambers - 2
Design Flow - 11.5 MGD
Design Flow Velocity - 1 foot/second
Grit Characteristics
  10 - 94% organics
  Settling rate 4 feet, minimum
  Specific gravity average ~1.5-2.0
Overflow rate 42,800 gallons/day/feet^2
Flow Control - Parshall Flume
Volume of Grit -
  Maximum - 520 cubic feet/day
  Average - 260 cubic feet/day
Grit Removal - mechanical - continuous
Grit Disposal - landfill
Dimensions - single chamber 56 feet x 5 feet 4 inches
Detention Time
  Working - 37 seconds
  Total - 56 seconds
Volume - 333 cubic feet, each
Total Area Requirements: 90 feet x 10 feet (including inlet and outlet)

6. <u>Neutralization</u>

A. Chambers
  Number required - 2
  Shape - cubicle
  Detention Time - 10 minutes at design flow (11.5 MGD)
  Working Volume - 4,050 feet^3 (30,300 gallons)
  Interior Working Dimensions - 16 feet x 16 feet x 16 feet
Approximate Exterior Dimensions - 18.5 feet x 18.5 feet x 18.5 feet
Baffles - baffles to prevent vortexing and influent short circuiting

Agitation - 35 horsepower per chanber, turbine
type mixers

Type of Control - feedback pH recorder control -
Control valves should have linear
trim with positioners

Neutralization - (Chemical Usage, Chemical Storage,
Slaking, Feeding)

Waste Acidity - Average 100,500 pounds/day ($CaCO_3$)
Maximum 426,000 pounds/day ($CaCO_3$)

Lime Utilization - At average - 50%
At maximum - 75%

Neutralizing Agent - High Calcium Quicklime

Design Feed Rate Average - 200,000 pounds/day ($CaCO_3$)
- 112,000 pounds/day (CaO)
Maximum - 640,000 pounds/day ($CaCO_3$)
- 410,000 pounds/day (CaO)

Storage Capacity - 7 days based on average usage

Number of Storage Silos - 4

Silo Capacity - 34,000 gallons (each)

Feeder Capacity - Maximum - 90,000 pounds CaO/day (each)
Range - 15,000-90,000 lbs CaO/day

Number of Slakers - 2

Capacity of Slakers - Maximum-180,000 lbs CaO/day (each)
Range-15,000-100,000 lbs CaO/day
(each)

7. <u>Flocculation</u>

A. <u>Chamber</u>

Tank Shape - rectangular with rounded fillets
along the bottom sidewall.
Sidewall depth - 10 feet

Paddles - four bladed paddles running the
width of the chamber with a tip
speed of 2 feet/second
detention time 15 minutes

Baffles - baffling between flocculation and
sedimentation

Dimensions - 75 feet x 8 feet x 10 feet

B. <u>Polyelectrolyte</u>

Polyelectrolyte - Atlas 2A2
Addition Range - from 0.25 mg/l at 8.75 MGD to 1.5 mg/l at 11.5 MGD or 18.3 lb/day - 144 lb/day
Normal Operation - 0.5 mg/l at 8.75 MGD
Solution Concentration - 0.4% solution

8. <u>Solids and Scum Removal</u>

The existing facilities will be used with required repairs or modifications.

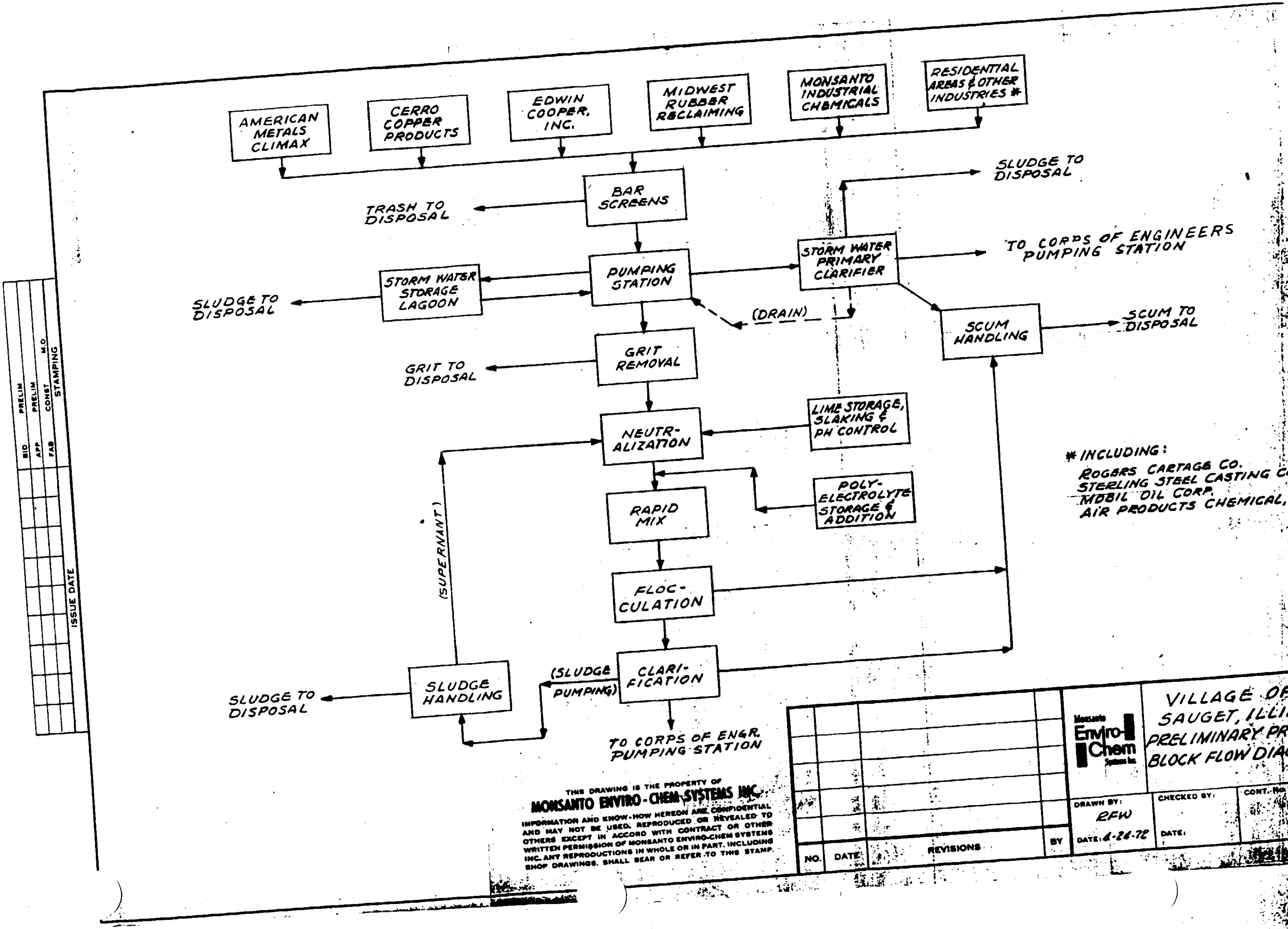
9. <u>Sludge Handling & Vacuum Filtration</u>

Sludge Handled - 79,000 lbs/day
Filter Loading Rate - 2.0 lbs/ft^2/day
Period of Operation - 24 hours/day
Total Filter Area - 1250 square feet
Space Required - 56 feet x 49 feet for two filters
- 56 feet x 24 feet for future expansion
Ultimate Disposal - Landfill

10. <u>Flow Measurement and Sampling</u>

Flow measurement - Parshall Flume
Sampling - Continuous, flow proportioned sample for -

1. Raw waste before neutralization
2. Effluent from clarifiers


AMERICAN METALS CLIMAX
CERRO COPPER PRODUCTS
EDWIN COOPER, INC.
MIDWEST RUBBER RECLAIMING
MONSANTO INDUSTRIAL CHEMICALS
RESIDENTIAL AREAS & OTHER INDUSTRIES *
BAR SCREENS
TRASH TO DISPOSAL
PUMPING STATION
STORM WATER STORAGE LAGOON
SLUDGE TO DISPOSAL
STORM WATER PRIMARY CLARIFIER
SLUDGE TO DISPOSAL
TO CORPS OF ENGINEERS PUMPING STATION
(DRAIN)
SCUM HANDLING
SCUM TO DISPOSAL
GRIT REMOVAL
GRIT TO DISPOSAL
NEUTR-ALIZATION
LIME STORAGE, SLAKING & PH CONTROL
RAPID MIX
POLY-ELECTROLYTE STORAGE & ADDITION
FLOC-CULATION
CLARI-FICATION
(SUPERNANT)
SLUDGE HANDLING
(SLUDGE PUMPING)
SLUDGE TO DISPOSAL
TO CORPS OF ENGR. PUMPING STATION
* INCLUDING:
ROGERS CARTAGE CO.
STERLING STEEL CASTING C
MOBIL OIL CORP.
AIR PRODUCTS CHEMICAL,
BIO PRELIM
APP PRELIM
FAB CONST M.O.
STAMPING
ISSUE DATE
THIS DRAWING IS THE PROPERTY OF
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Monsanto Enviro-Chem Systems Inc.
DRAWN BY: RFW
DATE: 4-24-72
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CONT. No.
VILLAGE OF
SAUGET, ILLI
PRELIMINARY PR
BLOCK FLOW DIA

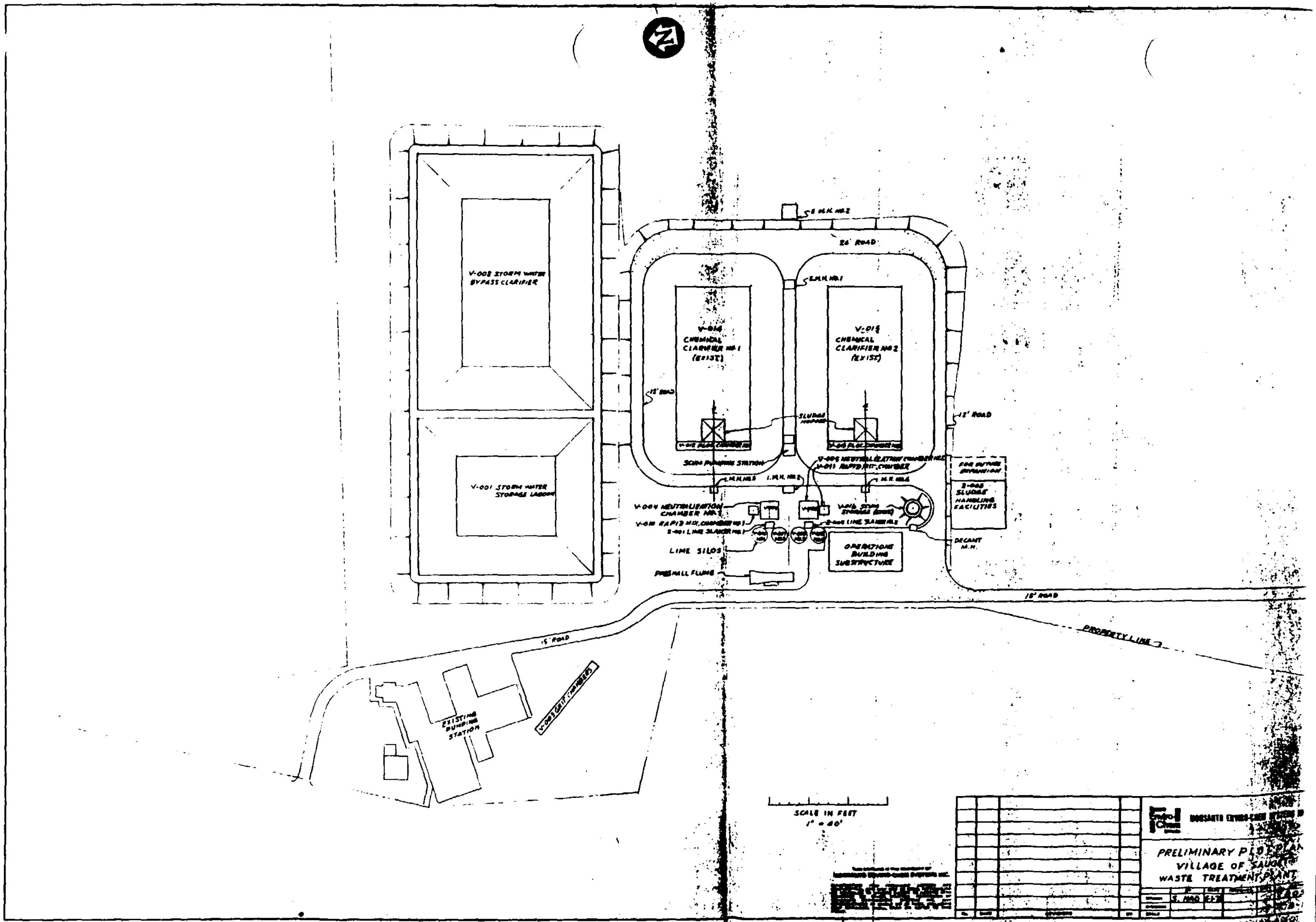

V-003 STORM WATER BYPASS CLARIFIER
V-001 STORM WATER STORAGE LAGOON
CHEMICAL CLARIFIER NO 1 (EXIST)
V-013 CHEMICAL CLARIFIER NO 2 (EXIST)
26' ROAD
12' ROAD
15' ROAD
18' ROAD
SLUDGE HOPPER
LIME SILOS
PARSHALL FLUME
OPERATIONS BUILDING SUBSTRUCTURE
SLUDGE HANDLING FACILITIES
FOR FUTURE EXPANSION
DECANT M.H.
EXISTING PUMPING STATION
PROPERTY LINE
SCALE IN FEET
1" = 40'
PRELIMINARY PLOT PLAN
VILLAGE OF SAUGET
WASTE TREATMENT PLANT

TABLE 3

Recommended Waste Reductions within the Village of Sauget, Illinois

Contributor	Item
American Zinc or American Metals Climax	Flow Metals losses
Edwin Cooper	Flow Floating Oil & Scum BOD_5 especially low molecular weight organics Odor causing wastes Color Bodies
Cerro Copper	Metals losses
Midwest Rubber Reclaiming	Flow BOD_5 Rubber Odor Causing Wastes Color Bodies
Monsanto Industries Chemicals Co.	Flow Color Bodies Phenols & other Aromatics BOD_5 Odor Causing Wastes Chlorine Dumps

Dissolved Solids - Each industry should evaluate costs for reducing dissolved solids discharges. At this time the technology available for removal of dissolved solids from the Village effluent is unproven on this scale and costs are extremely high and uncertain.

Cyanide - No major source was found to explain the levels of cyanide present in the total Village waste.

SCHEMES OF PILOT PLANT OPERATION AND SEQUENCE OF EVENTS

Prior to pilot plant start-up on May 1, 1971, bench-scale operations were conducted to decide which process alternatives should undergo pilot plant evaluation. The bench-scale tests are discussed in the report issued July 20, 1971, entitled "Preliminary Laboratory and Inplant Studies." Based on results of the bench-scale work, it was decided to evaluate neutralization, flocculation, and clarification, followed by biological treatment or activated carbon. To carry out multiple investigations, the pilot plant was operated using five separate operating schemes. The schemes are shown in Figure 3 , and the arrangement of the equipment is illustrated in Drawings 3-10 and 3-11.

In all the schemes of operation, the waste was treated by the chemical treatment system consisting of grit removal, lime addition, flocculation, and sedimentation. The chemical system was started up on May 1, 1971, and data was recorded continuously from May 11, 1971, through August 29, 1971. Twenty-four hour continuous samples were taken from the raw waste line and from the chemical system effluent line. The plant was operated at average flow rate of 0.57 gpm with a resulting clarifier overflow rate of 470 gal/day-ft^2. Flocculation and clarification were carried out in the chemical system clarifier (T-5). The clarifier had a center well which extended down the full side wall depth. A clock motor rotated a shaft with small extended blades to accomplish flocculation. The remaining equipment configuration is shown in Drawing 3-10.

Scheme A consisted of operating the chemical system and treating the effluent biologically or with activated carbon. During the evaluations, polyelectrolytes were added to the center well of the clarifier or to the neutralization tank.

Four-inch diameter carbon columns were operated during Scheme A from 5/10/71 through 7/16/71. Three experimental carbon runs were completed during this period. The biosystem was operated as shown in Drawing 3-10 from 5/12/71 through 7/9/71. A continuous air stripping experiment was run in parallel to the biosystem from 6/5/71 through 7/9/71 and the purpose of this was to determine if air stripping was the mechanism of organic removal experienced in the biological system.

Two experiments were conducted between the periods of Scheme A and Scheme B, while the chemical treatment system continued operation. The tests were as follows:

a) The comparative carbon studies were started on 7/16/71 and finished on 7/25/71. The purpose of these studies was to compare relative adsorption rates of different carbons. Details of the work are discussed in Section D of the carbon study discussion.

b) On 7/31/71, jar tests were started to evaluate various types of polyelectrolytes for reducing the effluent suspended solids from the chemical system. These tests were completed on 8/7/71.

Scheme B of the pilot plant operation was started on 8/15/71 and continued through 8/29/71. During the pilot plant operations, there was concern as to whether the effluent from the chemical system would meet proposed State heavy metals criteria. Sulfide and hydroxide treatment were evaluated as separate unit operations. The equipment layout is shown in Drawing 3-11.

Between Schemes B and C, centrifuge experiments were conducted utilizing pilot plant sludge. These experiments were conducted using a leased laboratory scale bowl-type centrifuge and lasted from 8/28/71 through 9/11/71.

Scheme C consisted of evaluating Darco carbon after one regeneration. One-and-three-quarters inch diameter columns were used for this work. The chemical treatment system was operated with sulfide addition prior to clarification. Scheme C lasted from 9/10/71 through 9/11/71.

Between Schemes C and D, vacuum filtration experiments were carried out, utilizing pilot plant sludge. These experiments were commenced on 9/22 and were completed on 9/25.

Scheme D began on 10/1/71, and consisted of evaluating Witco carbon after one regeneration, and Darco carbon after a second regeneration. Multimedia filtration was evaluated as a unit operation during this period prior to carbon treatment. The multimedia filter was evaluated during schemes D and E. Sulfide was injected as in Scheme C. Scheme D was completed on 11/17/71. Scheme E involved final carbon regeneration studies. Thrice regenerated Darco, once regenerated Darco, and once regenerated acid-washed Darco were evaluated in the 1.75 inch diameter carbon columns. During this scheme, the clarifier in the chemical system was operated at an overflow rate 1000 gal/day-ft^2; sulfide was not added. The multimedia filter was also evaluated. With the termination of Scheme E on 11/17/71, the pilot plant was shut down.

FIGURE 3

SCHEMES OF CONTINUOUS OPERATION

PILOT PLANT

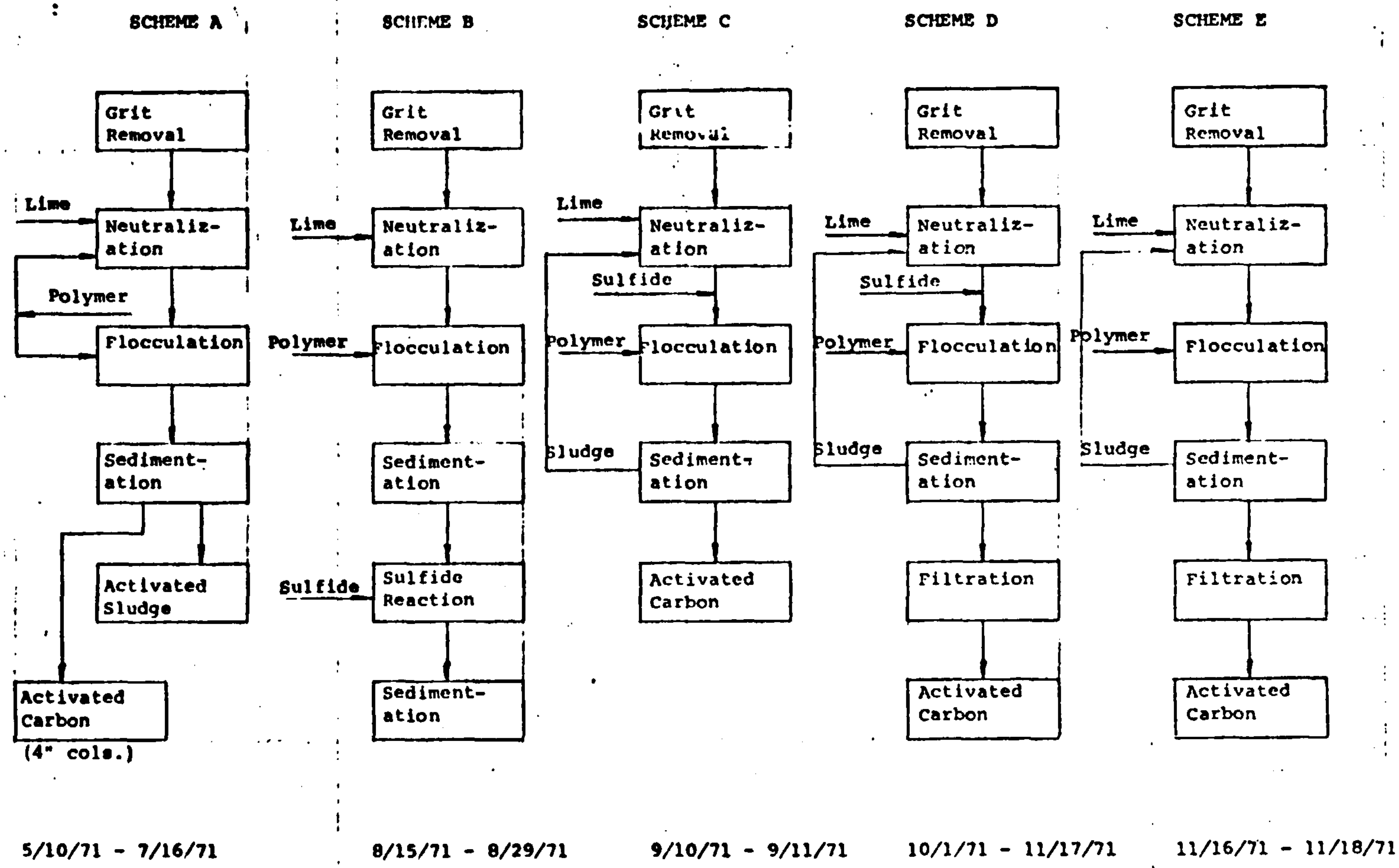


TABLE 4

SCHEDULE OF EVENTS

DATE (1971)	SCHEME	DESCRIPTION
5/1		Start-up Pilot Plant
5/10	A	Activated carbon - 4 inch ϕ column
5/12	A	Activated sludge-start-up
6/5		Continuous air stripping experiment - start-up
6/30		American Zinc shutdown
7/9		Continuous air stripping experiment - finish
7/9	A	Activated sludge shutdown
7/16	A	Activated carbon shutdown 4 inch ϕ column Comparative carbon studies start 1. Darco vs. Pittsburgh 2. Darco vs. Witco 3. Darco vs. Nuchar (1.75 inch ϕ column)
7/25		Comparative carbon studies - finish
7/31		Polyelectrolyte Jar tests - start
8/7		Polyelectrolyte Jar tests - finish
8/15	B	Sulfide precipitation start-up (continuous)

TABLE 4

SCHEDULE OF EVENTS (con't)

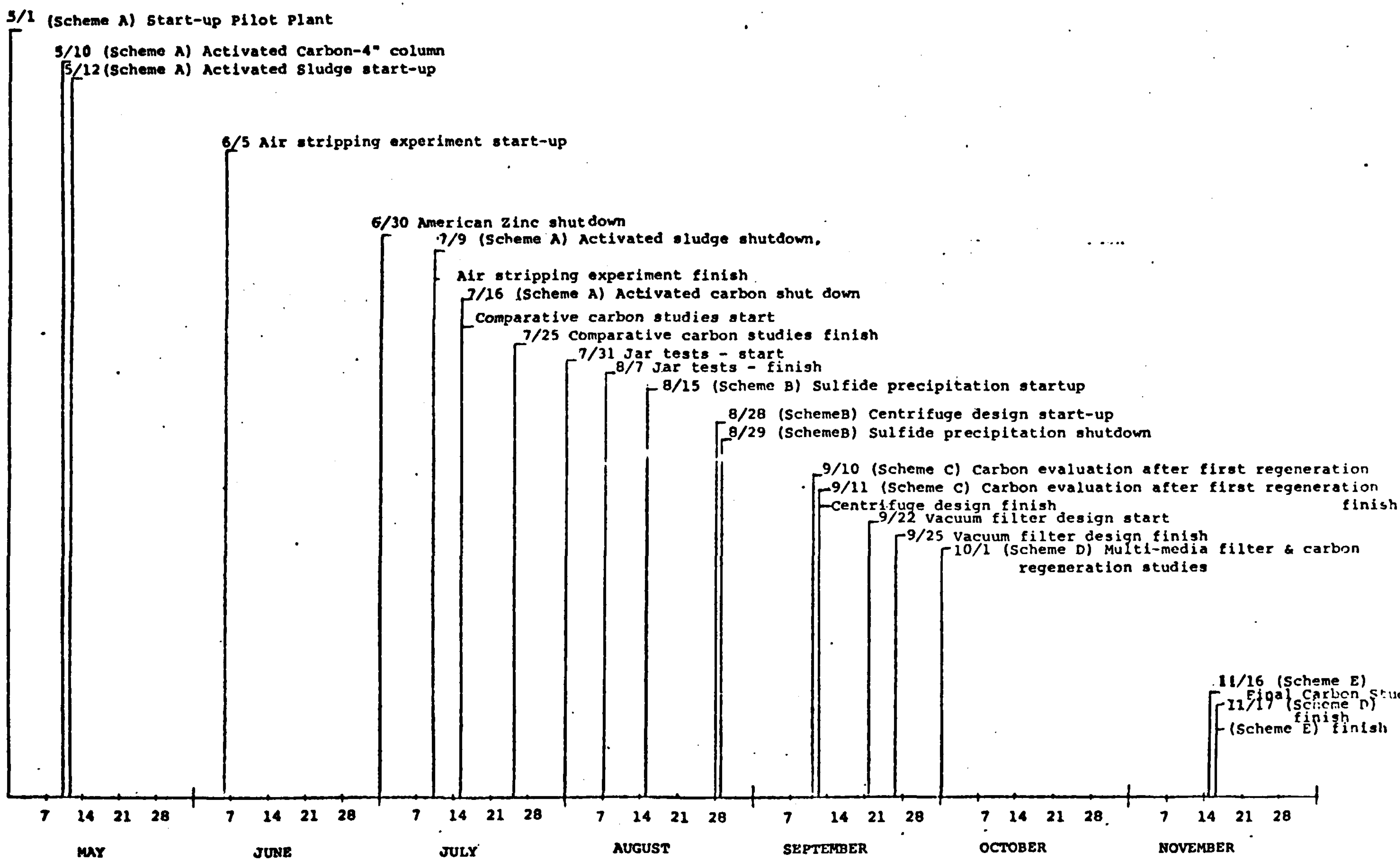
DATE	SCHEME	DESCRIPTION
8/28	B	Centrifuge test start-up
8/29	B	Sulfide precipitation shutdown
9/10	C	Carbon evaluation after first regeneration (Darco) - start
9/11	C	Carbon evaluation after first regeneration - finish
9/11		Centrifuge test finish
9/22		Vacuum filter test start
9/25		Vacuum filter test finish
10/1	D	Multi-media filter and carbon regeneration studies 1. Witco-one regeneration 2. Witco-virgin 3. Darco-2nd regeneration 4. Darco-virgin
11/16	E	Final carbon studies 1. Darco-3rd regeneration 2. Darco-first regeneration acid wash 3. Darco-first regeneration 4. Darco-virgin
11/17	D	Finish
11/17	E	Finish

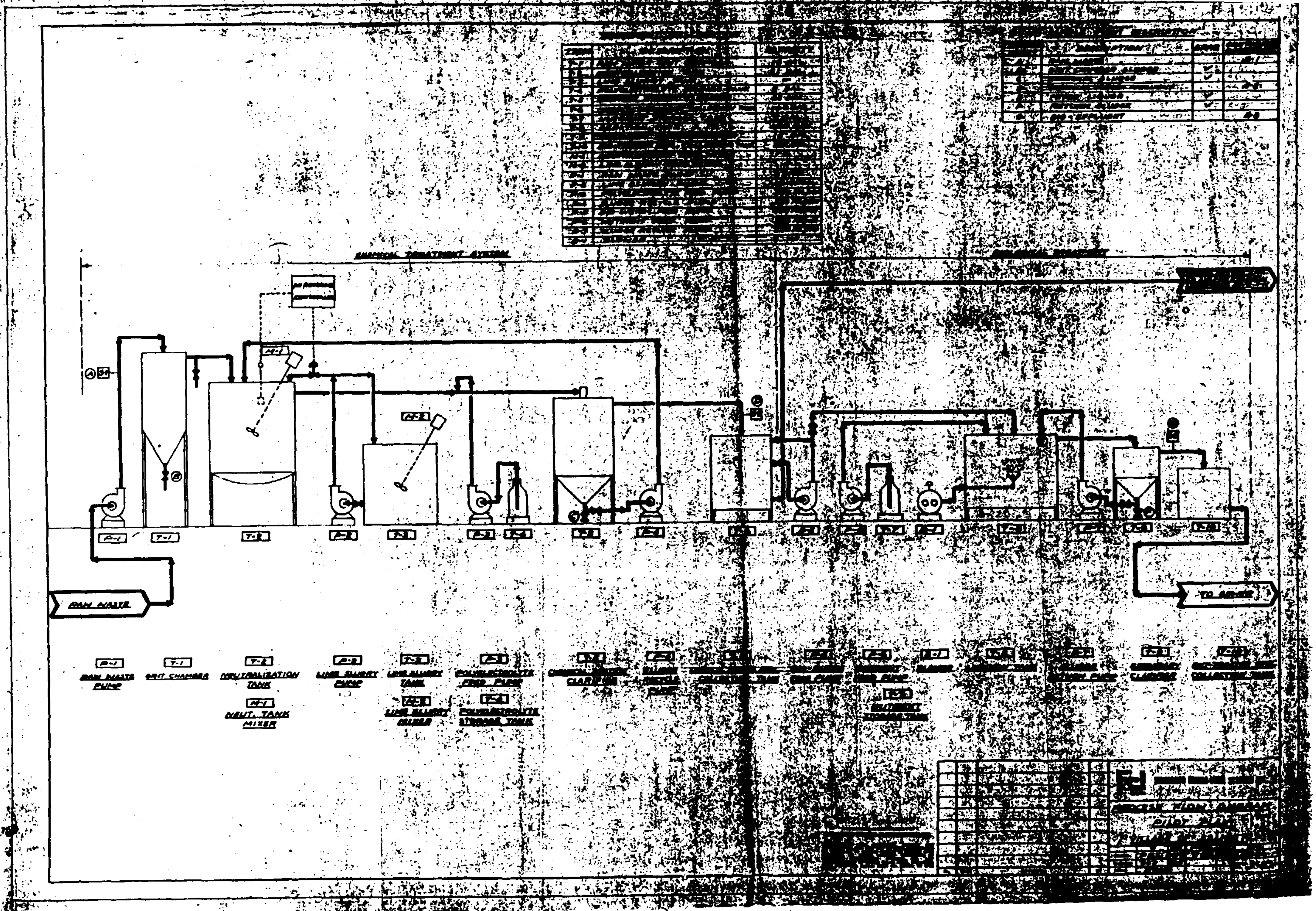
FIGURE

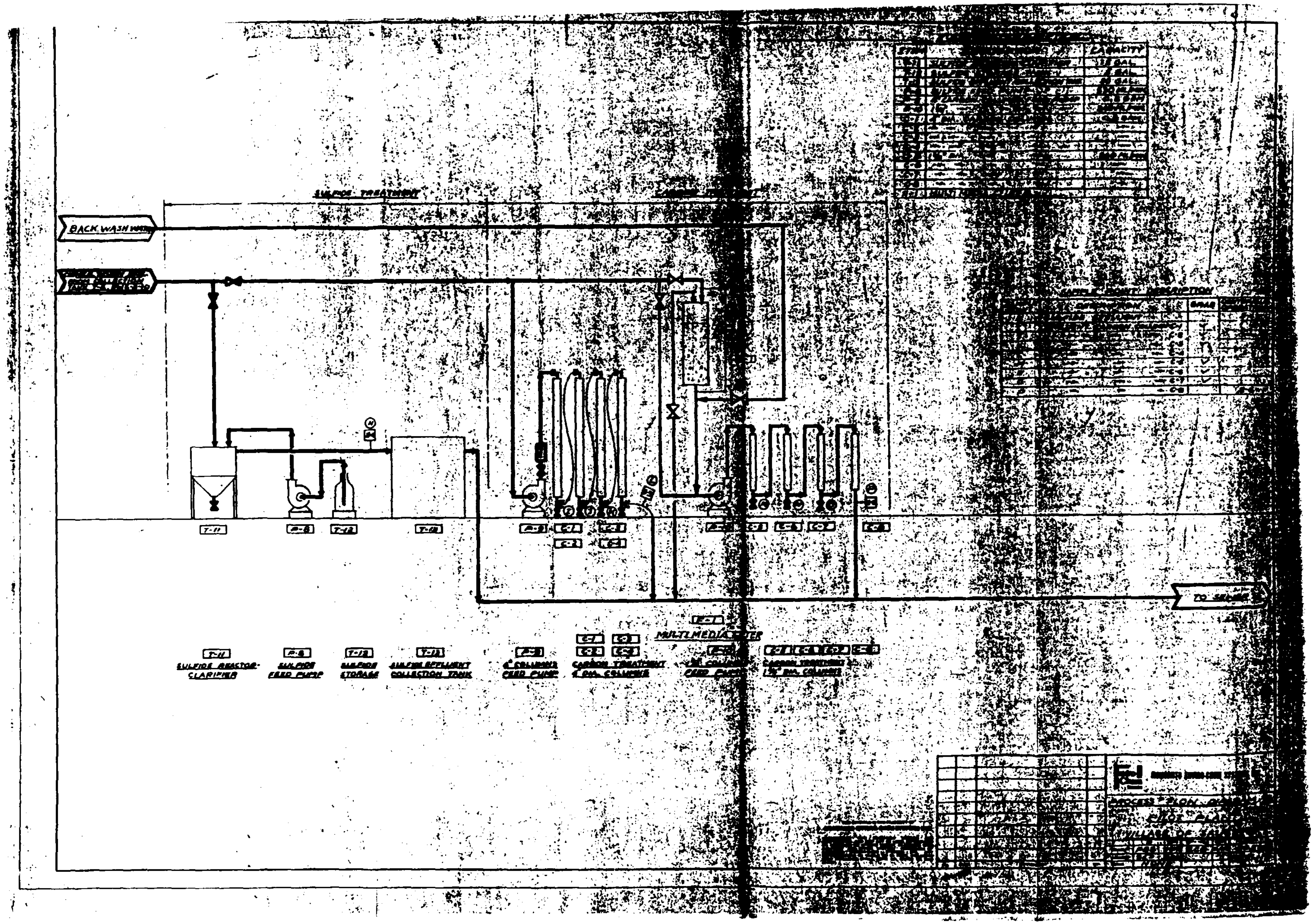
SCHEDULE OF EVENTS

PILOT PLANT

SAUGET, ILLINOIS




CHEMICAL TREATMENT SYSTEM
RAW WASTE
TO SEWER
P-1
RAW WASTE PUMP
T-1
GRIT CHAMBER
T-2
NEUTRALIZATION TANK
M-1
NEUT. TANK MIXER
P-2
LIME SLURRY PUMP
T-3
LIME SLURRY TANK
M-2
LIME SLURRY MIXER
P-3
POLYELECTROLYTE FEED PUMP
T-4
POLYELECTROLYTE STORAGE TANK
CHEMICAL CLARIFIER
PROCESS FLOW DIAGRAM
PILOT PLANT



SULFIDE TREATMENT
BACK WASH
T-11
P-8
T-12
T-13
P-3
C-1
C-2
C-3
C-4
F-1
MULTIMEDIA FILTER
C-5
C-6
C-7
C-8
TO SEWER
T-11 SULFIDE REACTOR-CLARIFIER
P-8 SULFIDE FEED PUMP
T-12 SULFIDE STORAGE
T-13 SULFIDE EFFLUENT COLLECTION TANK
P-3 4" COLUMNS FEED PUMP
C-1 C-2 C-3 C-4 CARBON TREATMENT 4" DIA. COLUMNS
CARBON TREATMENT 1½" DIA. COLUMNS
CAPACITY
PROCESS FLOW
PILOT PLANT

Description of Individual Contributors Waste Streams 1971

The flows for the industries to the Village of Sauget sewer system were determined as of December 22, 1970. The determinations were used as a basis for flow information during the pilot plant run. The individual waste streams from the Village were characterized and each industry's waste stream is discussed individually. Samples were obtained using the Hodges Sampler, (Figure 5), a slow pull continuous sampler capable of delivering 16 ounces per hour, with the option of collecting the sample for periods ranging from one hour to 3 days. The samples for solids and COD information (Table 5) were obtained during the flow measurement study completed on 12/22/70. The samples for dissolved solids and the analyses shown in Table 7 were obtained during May and June of 1971, with specific dates indicated. The samples for BOD_5 determination were obtained during the various inplant studies. Changes from the waste character shown and volume described here are expected based on proposed inplant work by the individual contributors. These changes will be discussed in subsequent sections.

American Zinc/American Metals Climax

American Zinc shut down its operations at Sauget during the last week in May, 1971. Water was discharged from the plant during the month of June, and the discharge ceased during the last week in June. While American Zinc was operating, the major water source was once through cooling water from the evaporative cooling system. Sources of contamination include carry over from the evaporative cooling system, wash down and normal drainage from the Cell Room basement. City and well water were used as a water supply with the well water making up a majority of the supply. The well water was highly contaminated with 2000 mg/l of dissolved solids.

Major contaminants from American Zinc included zinc, iron, cadmium and magnesium. Over 2000 pounds per day of zinc were discharged.

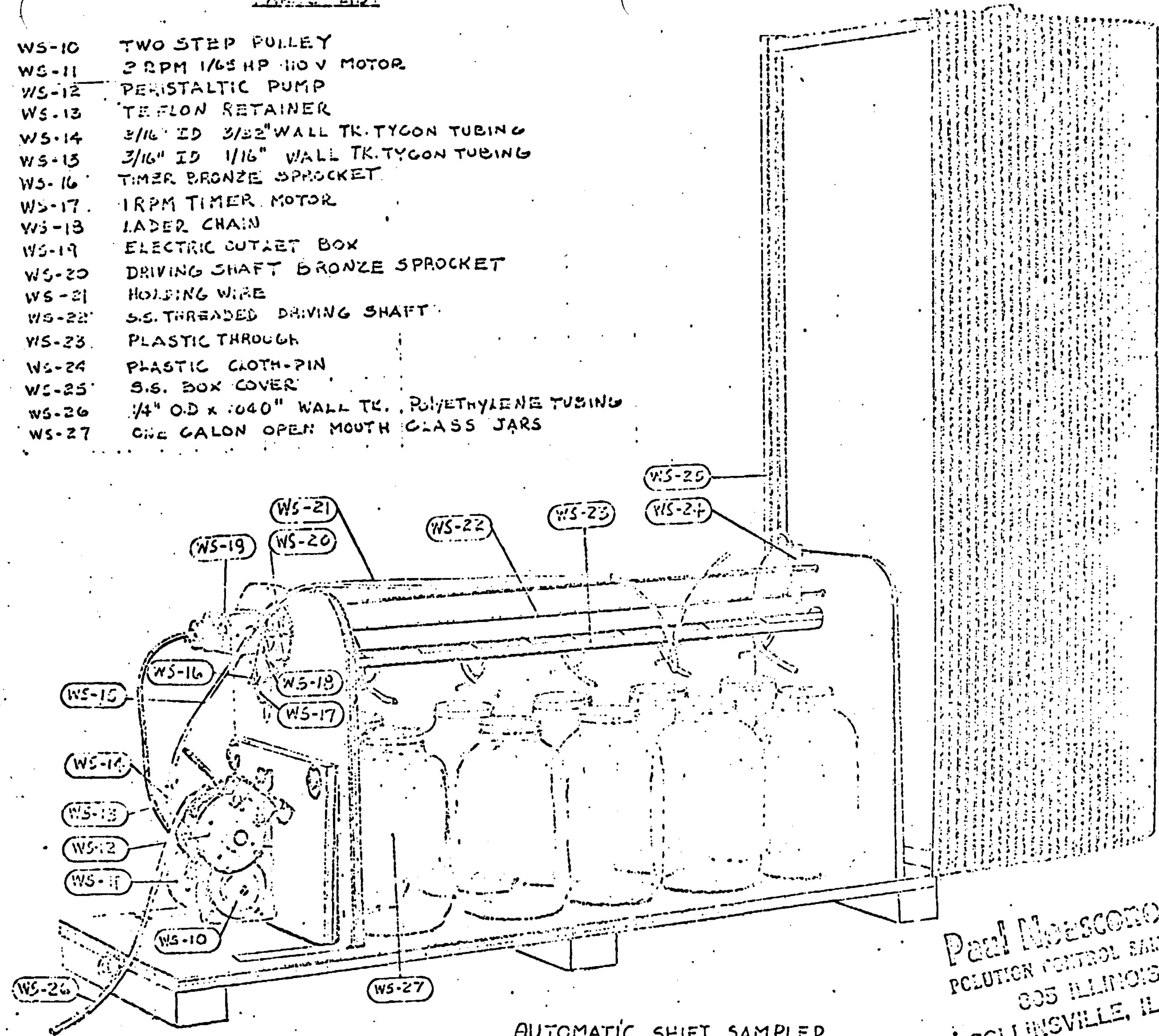
American Metals Climax is considering acquisition of the American Zinc facility. If and when AMAX acquires the plant, the effluent will change from what was observed during the pilot plant operation.

FIGURE 5

HODGES SAMPLER

PARTS LIST

WS-10	TWO STEP PULLEY
WS-11	2 RPM 1/65 HP 110 V MOTOR
WS-12	PERISTALTIC PUMP
WS-13	TEFLON RETAINER
WS-14	3/16" ID 3/32" WALL TK. TYGON TUBING
WS-15	3/16" ID 1/16" WALL TK. TYGON TUBING
WS-16	TIMER BRONZE SPROCKET
WS-17	1 RPM TIMER MOTOR
WS-18	LADER CHAIN
WS-19	ELECTRIC OUTLET BOX
WS-20	DRIVING SHAFT BRONZE SPROCKET
WS-21	HOISING WIRE
WS-22	S.S. THREADED DRIVING SHAFT
WS-23	PLASTIC THROUGH
WS-24	PLASTIC CLOTH-PIN
WS-25	S.S. BOX COVER
WS-26	1/4" O.D x .040" WALL TK. POLYETHYLENE TUBING
WS-27	ONE GALON OPEN MOUTH GLASS JARS



AUTOMATIC SHIFT SAMPLER

Cerro Copper & Brass Company

Cerro's operation in Sauget produces copper tube and electrolytically refined copper in ingot form by processing various grades of scrap. No ore is processed at Sauget and no brass is produced.

Water is obtained from the city and from deep wells within the plant. Sources of contaminants include the air pollution scrubbing system off the various furnaces in the plant, the quenching operation and cell house losses. Major contaminants include copper, zinc and nickel. Cerro contributes a moderate amount of suspended solids, roughly 18 per cent of the Village total, and a low amount of organic load as COD, 2.4 per cent of the total.

Edwin Cooper

Edwin Cooper, Inc. acquired the former North area of Monsanto's W. G. Krummrich Plant as of June 1, 1971. Edwin Cooper, Inc. produces oil additives from this facility as well as some intermediate chemicals for Monsanto. The waste contamination results from normal production as well as cleaning and washing operations. Cooper contributes roughly 19 per cent of the organic load and 12 per cent of the solids load to the Village. Numerous dumps of floating solids and oily material were attributed to Cooper's waste which has a pH of between 1-2. The low molecular weight organics in the waste (i.e., methanol) exhibit a BOD_5 which is not amenable to removal by carbon treatment.

Midwest Rubber

Midwest Rubber Reclaiming Company reclaims scrap rubber at Sauget. 2 million gal/day of deep well water is the primary source of water. Organic contamintion results from the devulcanizing process either through air pollution control or through a solubilizing process (a high BOD_5 load.) Midwest contributes approximately 10 per cent of the Village COD load. Solids mostly in the form of rubber particles contribute 6.5 per cent of the total Village load. Currently the cooling water is used on a once through basis. The major inorganic contaminant found was zinc, measured at roughly 40 pounds per day maximum. The zinc is discharged from the wet devulcanizing process.

Monsanto

The W. G. Krummrich Plant is engaged in the manufacture of various inorganic and organic chemicals which are used in many different areas ie. rubber additives, plasticizers and hydraulic fluids. The waste stream leaving the plant has a flow rate of 12.65 mgd. The major water source is well water. The waste stream is highly acidic and contains nitric, sulfuric and hydrochloric acids. Free chlorine is present in the total Village waste stream periodically in concentrations as great than 30 mg/l because of dumps from the Krummrich Plant. Chlorinated and nitrated aromatics are present in the waste and several of these compounds contribute to the reddish brown to straw yellow hue of the Village waste. The color of the waste is in excess of 500 APHA units. The Krummrich waste is the major source of organic contamination as can be seen from the COD values in (Table 5).

Village of Sauget (Residential Areas & Other Industries)

The Village of Sauget has approximately 200 residents not mentioned above including: Rodgers Cartage, Inc., Air Products Chemical Inc., Sterling Steel Casting Company and Mobil Oil. The waste from the Village and other contributors is expected to contain 200 pounds of solids and [illegible] pounds of COD based on values measured during the flow study.

TABLE 5

VILLAGE OF SAUGET
CONTAMINANT DISTRIBUTION

Contributor	Pounds Solids/Day	Pounds Nos. BOD_5/Day	Pounds lbs COD/Day	lbs Dissolved Solids/Day	pH
American Zinc Company	2,160	100	1,275	5,361	6-7
Cerro Copper & Brass Co.	5,122	mg/l	2,528	17,275	4-5
Edwin Cooper	3,440	3,120	20,000	110,900	1-2
Mobil Oil Co.	7	mg/l	mg/l	91	6-7
Monsanto Industrial Chemicals Company	15,217	18,500	73,876	301,315	1-2
Midwest Rubber Company	1,845	6,350	5,740	28,000	7-9
Sterling Steel Casting Company	75	*	*	*	*
Village of Sauget	330	200	2,186	249	6-7
TOTALS	28,196	28,270	105,605	509,191	

*Included in Village total

TABLE 6

VILLAGE OF SAUGET

WASTE WATER DISTRIBUTION

Contributor	Avg. Flow gpm	Equalization Factor	Equalized Avg. Flow (gpm)	Equalized Avg. Flow (MGD)	Distribution % of Flow
American Zinc Company	3,020	1	3,020	4.34	18.111
Cerro Copper & Brass Co.	1,800	0.97	1,745	2.51	10.474
Edwin Cooper	1,530	1	1,530	2.20	9.181
Mobil Oil Co.	30	1	10	0.014	0.058
Monsanto Co.	8,785	1	8,785	12.65	52.791
Midwest Rubber Co.	1,765	0.82	1,450	2.09	8.722
Sterling Steel Casting Co.	50	1	50	0.072	0.300
Village of Sauget	70	1	70	0.101	0.421
TOTALS	17,050			23.963	100.000
	24.5 MGD				

TABLE 7

CONCENTRATION OF METAL DETECTED mg/l

No.	Sample	Cr(VI)	Cr Total	Fe (Dis-solved)	Fe (Total)	Cu	Ni	Mn	Zn	Cd	B	Ba	Pb	Ag	Se	As
71-201	Monsanto Edw. Cooper Study 6/19	N.D.	0.19	90	97	0.33	5.0	1.9	4.1	0.050	0.54	1.7	0.52	0.11	N.D.	0.23
71-202	Primary Eff. 6/24	N.D.	N.D.	N.D.	0.50	N.D.	0.53	0.70	13.0	0.093	0.40	N.D.	N.D.	N.D.	N.D.	0.14
71-203	Final Eff. 6/24	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	2.6	N.D.	N.D.	1.0	1.8	N.D.	N.D.	N.D.	0.20
71-204	Midwest Rubber E-W Comp. 5/25	N.D.	N.D.	N.D.	7.3	0.081	N.D.	0.98	2.2	N.D.	0.65	1.2	N.D.	N.D.	N.D.	N.D.
71-205	Amer. Zinc. E-W Comp. 5/14	N.D.	N.D.	5.5	23	2.5	0.52	8.2	67	0.27	0.85	N.D.	0.57	0.04	N.D.	N.D.
71-206	Cerro Adm. Bld. 5/13 Dead Creek Comp.	N.D.	N.D.	N.D.	177	0.38	4.9	2.1	11	0.40	0.72	N.D.	N.D.	N.D.	N.D.	N.D.
71-208	Dept. 254 Comp. 5/24	N.D.	N.D.	N.D.	0.24	N.D.	N.D.	0.072	N.D.	N.D.	0.24	N.D.	N.D.	N.D.	N.D.	N.D.
71-209	Dept. 254 Comp. 5/25	N.D.	N.D.	0.35	0.35	N.D.	N.D.	0.078	N.D.	N.D.	0.22	N.D.	N.D.	N.D.	N.D.	N.D.
71-210	Dept. 254 Comp. 5/26	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	0.047	N.D.	N.D.	0.25	N.D.	N.D.	N.D.	N.D.	N.D.
71-211	24 W Comp. 5/24	0.080	0.080	24	39	2.7	1.9	0.85	2.4	0.091	0.32	N.D.	1.4	0.09	N.D.	0.02
71-212	24 W Comp. 5/25	0.14	0.13	47	57	3.2	2.7	0.88	3.1	0.13	0.53	N.D.	2.4	0.12	N.D.	0.017
71-213	24 W Comp. 5/26	0.075	0.085	33	52	3.3	3.2	0.87	3.4	0.13	0.38	N.D.	2.2	0.14	N.D.	0.034
71-214	30 W Comp. 5/24	0.14	0.16	6.7	6.9	0.13	0.17	0.67	0.58	0.019	0.38	N.D.	0.15	0.13	N.D.	0.022
71-215	30 W Comp. 5/25	0.13	0.52	8.5	8.9	0.10	0.25	0.73	0.38	0.021	0.05	N.D.	N.D.	N.D.	N.D.	N.D.
71-216	30 W Comp. 5/26	0.14	0.50	24	24	0.12	0.23	0.84	0.70	0.022	0.23	N.D.	N.D.	N.D.	N.D.	0.014
71-217	Prim-Eff. 6/28	N.D.	N.D.	0.37	3.1	0.077	0.29	0.47	3.0	0.069	0.11	N.D.	N.D.	N.D.	N.D.	0.034
71-218	Bio Eff. 6/29	N.D.	0.030	0.32	2.3	0.14	0.27	0.37	2.4	0.059	0.39	N.D.	N.D.	N.D.	N.D.	0.023
Minimum Detection Limits		0.050	0.025	0.20	0.20	0.02	0.10	0.020	0.20	0.010	0.10	1.0	0.050	0.040	0.30	0.010

N.D. = Not Detected

DESCRIPTION OF RAW WASTE - 1971

The raw waste, as seen during the pilot plant operations from May through August of 1971 is summarized in Table 8 . The average flow to the waste treatment plant during this period was 18.75 MGD. The raw waste was out of compliance with the adopted State effluent criteria for the following:

pH, BOD_5, suspended solids, dissolved solids, copper, cyanide, iron - total and dissolved, lead, phenol, zinc, color, visible oil and grease and odor.

Several conditions occurred during pilot plant operations which are of importance:

1. Free chlorine dumps occurred on at least three occasions at levels which necessitated evacuation of the site. On 10/18/71 a sample was obtained which measured 30 mg/l as free chlorine.

2. The waste was observed to contain enough grit to fill the front portion of the clarifiers once every three months.

3. Large quantities of floating scum were observed to occur periodically.

The characteristics of the raw waste are further described in Appendix I in reference to specific concentrations of the many parameters measured during the pilot plant studies.

TABLE 8

RAW WASTE **
DATA SUMMARY
1971

Analysis	Average	Mean	+ σ	- σ	Range	Number of Observations
pH		1.9	2.5	1.6	1.3-7.3	79
COD		455	567	378	250-1630	86
BOD_5		70	109	41	26-300	20
Suspended Solids		47	109	20	8-394	56
Dissolved Solids	2950				2308-3846	8
Arsenic	ND					3
Barium	ND					3
Cadmium		0.12	0.18	0.04	0.02-0.56	13
Chromium	ND					3
Copper		1.2	2.0	0.4	0.5-3.2	14
Cyanide	0.032*					6
Flouride	0.58*					6
Iron (Total)	15.7					3
Iron (Dissolved)	16.6					11
Lead	2.1					3
Manganese	0.7					3
Mercury						
Nickel	0.3					3
Oil						
Phenol	6.0				3.5-7.3	5
Selenium	ND					3
Silver	ND					3
Zinc	9.6				2.7-20	7
Alkalinity (As $CaCO_3$)	1700					
Bacteria (Tot.Coliforms)					<2 -9	9
Settleable Solids (cc/l)	1.3					90
Color (APHA Units)	>500					
Floating Debris (FT^3/Day)	5*					
Visible Oil, Grease & Scum (FT^3/Day)	500*					
Threshold Odor Number	400					1

*Calculated
**American Zinc not operating, waste fed to Pilot Plant.

NOTE:
1. All concentrations in mg/l
2. ND = Not Detected

Table 9

COLOR vs. pH
SAUGET VILLAGE WASTE

pH	Dominant Wavelength	Purity	Hue
1.7	575	22%	yellow
3.2	572	24	greenish yellow
5.8	568	30	greenish yellow
7.3	572	44	greenish yellow
8.7	572	44	greenish yellow
11.1	573	44	greenish yellow

SUMMARY OF PROPOSED WASTE CHARACTERISTICS AS OF 1974+

Table 10 shows a summary of the proposed waste characteristics as of 1974+. These characteristics are to be used as a basis for the design of the chemical treatment system and were obtained by using the information supplied to Enviro-Chem by the industries of the Village.

Table 11 compares the 1974+ waste characteristics to the 1971 waste characteristics observed in the pilot plant and to the 1974 waste characteristics if the industries of the Village undergo only flow reduction with no change in the amount of contaminants presently discharged. If only flow reductions occur, the observed contaminant concentrations can be expected to increase by a factor of 2.05.

The expected contaminant reductions can be seen by comparing the pounds per day figures before reduction to those after reduction.

BOD5 is expected to remain roughly the same, an 11 per cent COD reduction is expected. Suspended solids are expected to increase by 25 per cent.

TABLE 10

PROPOSED WASTE CHARACTERISTICS
as of 1974 +

Item	Raw Waste	Water Supply	Raw Waste-Water Supply	Maximum
Flows				
GPM	6106	-	-	9046
MGD	8.79	-	-	13.02
BOD_5	14,110	250	13,860	-
COD	63,000	3700	59,300	-
Dissolved Organics	6000	1467	4533	10,300
Tot. Sus. Solids	22,000	1200	20,800	29,000
Tot. Dis. Solids	580,000	28,000	552,000	736,000
Oil (Hexane Solubles)	4600	359	4241	6340
pH	1-2	-	-	6
Phenols		107		
Arsenic (Total)	7.2	0.2	7.0	11.5
Barium (Total)	59	-	59	77
Cadmium (Total)	2.0	1.7	0.3	2.8
Chromium (Total+6)	12.5	1.7	10.8	14.3
Chromium (Total+3)	19.2	N.D.	19.2	33.2
Copper (Total)	191	2	189	231

Note:
1. All values in lbs/day except as noted.
2. - indiates no value.
3. ND indicates not detected.
4. Negative (-) values are to be considered as acidity.

TABLE (CONT'D)
PROPOSED WASTE CHARACTERISTICS (1974+)

Item	Raw Waste		Water Supply	Raw Waste-Water Supply		Maximum	
Cyanide	2.3		0.2	2.1		3.3	
Fluoride (Total)	40		47	-		50	
Iron (Total)	3138		139	2999		6042	
Iron (Dissolved)	1990		-	1990		3982	
Lead (Total)	137		8	129		175	
Manganese (Total)	104		14	90		140	
Mercury (Total)			N.D.				
Nickel (Total)	198		7	191		326	
Selenium (Total)	N.D.		N.D.	-		N.D.	
Silver (Total)	15.3		0.8	14.5		17.8	
Zinc (Total)	316		20	296		423	
Alkalinity(1) ($CaCO_3$)	~100,000		10,000	~90,000		~425,000	
Bacteria (Tot. Coliforms) (MPN)	Range	from	<2 to 9.				
Settleable Solids (cc/l)	1.3		N.D.	1.3		15	
Color (APHA Units)	>500		<5	-		>500	
Floating Debris (FT^3/Day)	5		N.D.	5		10	
Visible Oil, Grease & Scum (FT^3/Day)	500	(est.)	N.D.	500	(est)	750	(est
Threshold Odor Number	>400		N.D.	>400		>400	

TABLE 11

COMPARISON OF PRESENT RAW WASTE TO FUTURE RAW WASTE 1974

Item	Raw Waste 1971 Conc. mg/l	Raw Waste 1971 lbs/day	Raw Waste With Flow Reduction Only mg/l	Raw Waste With Flow Reduction Only lbs/day	1974+ Raw Waste With Flow And Contaminant Reductions mg/l	1974+ Raw Waste With Flow And Contaminant Reductions lbs/day
Flow	18.75 MGD		8.79 MGD		8.79 MGD	
BOD_5	70	11,000	149	11,000	149	11,000
COD	455	71,000	971	71,000	860	63,000
Suspended Solids	180	28,200	384	28,200	300	22,000
Dissolved Solids	2950	461,000	6293	461,000	7912	580,000
Arsenic	<0.01	-	<0.01	-	0.098	7.2
Barium	<1.0	-	<1.0	-	0.8	59
Cadmium	0.12	18.7	.26	18.7	0.027	2.0
Chromium +6	<0.05	-	<0.05	-	.17	12.5
Chromium +3	<0.05	-	<0.05	-	.26	19.2
Copper	1.2	187	2.6	187	2.6	191
Cyanide	0.032	5	.068	5	0.031	2.3
Flouride	0.58	91	1.2	91	1.0	74
Iron (Total)	15.7	2450	33	2450	43	3138
Iron (Dissolved)	16.6	2596	35	2596	27	1990
Lead	2.1	329	4.4	329	1.9	137
Manganese	0.7	109	1.5	109	1.4	104
Nickel	0.3	47	.64	47	2.7	198
Phenol	6.0	938	12.8	938		
Selenium	<0.3	-	<0.3	-	<0.3	-
Silver	<0.04	-	<0.04	-	0.21	15.3
Zinc	9.6	1500	20	1500	4.3	316
Acidity (As $CaCO_3$)	1700	266,000	3626	266,000	1364	100,000
Bacteria (Tot.Coliforms) MPN	<2-9	-	<2-9	-	<2-9	-
Color APHA	7500	-	7500	-	7500	-
Floating Debris (FT^3/Day)	5	-	5	-	5	-
Visible Oil, Scum & Grease (FT^3/Day)	500	-	500	-	500	-
Threshold Odor Number	400	-	>400	-	>400	-

Proposed Chemical System Effluent

The chemical system effluent as seen during the pilot plant operation is summed up in Table 12 . Table 13 shows the expected effluent characteristics in 1974. BOD_5 is expected to remain unchanged by the chemical system. A 37% COD reduction was experienced during the pilot plant studies and can be expected from the chemical system. A dissolved solids increase can be expected from the lime neutralization. The heavy metals effluent concentrations are expected to remain as experienced during the pilot plant.

Table 14 compares the pilot plant effluent and the expected effluent to the state effluent criteria. As can be seen BOD_5, dissolved solids, suspended solids and cyanide are not expected to be met. Phenol will probably not be met, however, at this time the Village has not released the expected phenol levels for design. Oil and mercury data have also not been released by the Village at this time.

TABLE 12

CHEMICAL SYSTEM EFFLUENT***
DATA SUMMARY 1971

Analysis	Average	Mean	+σ	- σ	Range	Number of Observations
COD		286	341	245	200-485	91
BOD_5		79	120	40	31-222	36
Suspended Solids*	56				18-158	18
Suspended Solids **		28	82	10	9-278	65
Dissolved Solids		4380	4820	3500	2885-6412	18
Arsenic	< 0.2					3
	0.087					2
Barium	ND					5
Cadmium		<0.01	0.043	<0.01	ND-0.41	46
Chromium	ND					5
Copper		0.12	0.23	0.05	0.01-1.4	60
Cyanide	0.037					2
Flouride	0.56					2
Iron (total)	1.7				ND-3.6	5
Iron (Dissolved)	ND					8
Lead	ND					
Manganese	.41				ND-.7	5
Mercury						
Nickel	.24				ND-.53	5
Oil						
Phenol	3.9				2.7-4.6	4
Selenium	ND					5
Silver	ND					5
Zinc		0.1	0.7	<0.01	<0.05-8.0	37

*Clarifier O.R. 1000 gpd/ft^2
**Clarifier O.R. 470 gpd/ft^2
***American Zinc Not Operating

NOTE:
1. All concentrations in mg/l
2. ND = Not Detected

TABLE 13

EXPECTED EFFLUENT CHARACTER
1974+

Item	8.79 MGD mg/l	8.79 MGD lb/day	11.5 MGD mg/l	11.5 MGD lb/day
BOD_5	150	11,000	150	14,400
COD	540	40,000	540	52,300
Total Suspended Solids	35	2,560	35	3,360
Total Dissolved Solids	11,700	860,000	11,700	1,120,000
As	0.08	6.4	0.08	7.7
Ba	N.D.	-	N.D.	-
Cd	N.D.	-	N.D.	-
Cr^{+6}	N.D.	-	N.D.	-
Cr^{+3}	N.D.	-	N.D.	-
Cu	0.12	8.8	0.12	11.5
CN^-	0.03	2.3	0.03	2.9
F	0.56	41	0.56	54
Fe (total)	1.7	125	1.7	163
Fe (dissolved)	N.D.	-	N.D.	-
Pb	N.D.	-	N.D.	-
Mn	0.41	30	0.41	39
Ni	0.24	18	0.24	23
Se	N.D.	-	N.D.	-
Ag	N.D.	-	N.D.	-
Zn	0.1	7.3	0.1	9.6
Acidity	N.D.	-	N.D.	-
Bacteria				
Total Coliform MPN	<10	-	<10	-
Settleable Solids cc/l	N.D.	-	N.D.	-
Color APHA	>500	-	>500	-
Floating Debris	N.D.	-	N.D.	-
Visible Oil	N.D.	-	N.D.	-
Scum & Grease				
Threshold Odor	>400	-	>400	-

TABLE 14

WASTE COMPARISON WITH STATE OF ILLINOIS STANDARDS

Analysis	State Standard (mg/l)	1971 Raw Waste (mg/l)	1971 Chemical Effluent (mg/l)	1974 Chemical Effluent	Chemical Effluent Compliance In	Out
pH	5-10	1.9	8.5	8.5	X	
BOD_5	20*	70	79	150		X
Suspended Solids	25	47	56	35		X
Dissolved Solids	2000**	2950	4380	11700		X
Arsenic (total)	0.25	N.D.	<0.2	.08	X	
Barium (total)	2.0	N.D.	N.D.	N.D.	X	
Cadmium (total)	0.15	0.12	<0.01	N.D.	X	
$Chromium^{+3}$ (total)	1.0	N.D.	N.D.	N.D.	X	
Copper (total)	1.0	1.2	0.12	0.12	X	
Cyanide	0.025	0.032	0.037	0.03		X
Fluoride (total)	2.5	0.58	0.56	0.56	X	
Iron (total)	2.0	15.7	1.7	1.7	X	
Iron (dissolved)	0.5	16.6	N.D.	N.D.	X	
Lead (total)	0.1	2.1	N.D.	N.D.	X	
Manganese (total)	1.0	0.7	0.41	0.41	X	
Mercury (total)	0.0005					
Nickel (total)	1.0	0.3	0.24	0.24	X	
Oil	15.0					
Phenol	0.3	6.0	3.9			X
Selenium (total)	1.0	N.D.	N.D.	N.D.	X	
Silver	0.1	N.D.	N.D.	N.D.	X	
Zinc (total)	1.0	9.6	0.1	0.1	X	

* Proposed
**Estimated for the Village of Sauget

TABLE 14A

MASTER DATA
CHEMICAL SYSTEM EFFLUENT

Day No.	Date	pH	Temp. (°F)	BOD5*	COD5*	Total Solids*	Susp. Solids*	% Volatiles	Dissolv. Solids*	Phenols*	Free Chlorine*	Total Chlorine*	Phosphate*	Color (APHA)
1	5/11	8.9	76		254									300
2	5/12	8.9	66		210		18	83			<.01	<.01		350
3	5/13	8.5	68		206		35	37			<.01	<.01		400
4	5/14	8.8	76		306		44	52			<.01	<.01		350
5	5/15	8.6	74		247		14	100			<.01	<.01		400
6	5/16	8.7	74		250		25	40			<.01	<.01		>500
7	5/17	8.9	80		266	3801	52	6	3749	2.7	<.01	<.01		>500
8	5/18	8.6	77		274		86	12			<.01	<.01		>500
9	5/19	8.5	76		206		50	20			<.01	<.01		>500
10	5/20	9.0	76		338		156	12		3.7				>500
11	5/21	10.3	78		303	4273	82	5	4191		<.01	<.01		>500
12	5/22	8.7	68		251		15	66			<.01	<.01		>500
13	5/23		68											
14	5/24				322									
15	5/25	8.6	64	109	224		23	39						
16	5/26	7.9	65	211	267		37	49						
18	5/28	8.6												500
19	5/29	8.5			330		11	9						>500
20	5/30	8.4		101	227		49	41						500
21	5/31	8.3	76	130	283		33	58						>500
22	6/1	8.5	76	143	257		13	0			<.01	<.01		>500
23	6/2	8.5	75	116	344		44	1						>500
25	6/4	8.8	82	95	210		27	93		4.6				>500

*Values Reported in mg/l.

TABLE 14A

MASTER DATA
CHEMICAL SYSTEM EFFLUENT

Day No.	Date	pH	Temp. (°F)	BOD5*	COD5*	Kieldahl Nitrogen*	Total Solids*	Susp. Solids*	% Volatiles	Dissolved Solids*	Phenols*	Free Chlorine*	Total Chlorine*	Phosphate*	Color (APHA)
26	6/5	8.4	82	83	246			17	59		4.6				>500
27	6/6	8.4	85	77	222			31	35						>500
28	6/7	8.6	80	92	257	51.0	3593	58	31	3562					>600
29	6/8	8.7	78	112	264			27	26						>500
30	6/9	7.8	77	67	246			10	100						>500
31	6/10	8.6		47	248			28	0						>500
32	6/11	8.1	79	70	269			18	39						>500
33	6/12	8.3	85		200			21	43			<.01	<.01		>500
34	6/13	8.6	86	47	249			27	33			<.01	<.01		>500
35	6/14	8.8	82	223	433			9	100						>500
38	6/17	8.4		92	230			11	18						
39	6/18	8.4	82	125	277		4556	26	100	45[illegible]		<.01	<.01		>500
43	6/22			82	282			278	9						500
44	6/23	7.9		90	314			58	50						500
45	6/24	7.5		72	332			36	11						500
46	6/25	8.0	86		286		3347	16	75	3331					500
47	6/26	8.5	85	60	326			9	100						>500
48	6/27	8.2		66	200										250
49	6/28	8.3			290			12	75						>500
50	6/29				267			13	87						450
51	6/30	8.8			258										>500
52	7/1	8.0		167	350			103	65						>500
53	7/2	7.1	82	31	210			11	45						>500

*Values Reported in mg/l.

TABLE 14A

MASTER DATA
CHEMICAL SYSTEM EFFLUENT

Day No.	Date	pH	Temp. (°F)	BOD5*	COD5*	Total Solids*	Susp. Solids*	% Volatiles	Dissolv. Solids*	Phenols*	Free Chlorine*	Total Chlorine*	Phosphate*	Color (APHA)
54	7/3	10.0	82		263		42	29						>500
55	7/4	3.6	82		325		14	57						>500
56	7/5	11.9	79		306		33	37						>500
57	7/6	11.6	80	73	260		50	12						>500
58	7/7	8.6		75	349		63	51						
59	7/8	7.7		91	314									>500
60	7/9	7.8		110	424									
61	7/10	7.8		47	297									
62	7/11	7.4			291									
63	7/12	7.5		38	335									
64	7/13	7.6		20	276		12	33						
65	7/14	7.8		31	200		23	73						500
66	7/15	7.8		56	231		12	57						>500
67	7/16			45	235									
68	7/17				254									
71	7/20				266									
72	7/21	10.0			318									
73	7/22				330									
74	7/24				253		22	100						
75	7/25				306									
76	7/26	8.1			244		51	12						
77	7/27	8.5			288		104	5						
78	7/28	8.4			264		30	47						

*Values Reported in mg/l.

TABLE 14A

MASTER DATA
CHEMICAL SYSTEM EFFLUENT

Day No.	Date	pH	Temp. (°F)	BOD5*	COD5*	Total Solids*	Susp. Solids*	% Volatiles	Dissolv. Solids*	Phenols*	Free Chlorine*	Total Chlorine*	Phosphate*	Color (APHA)
79	7/29	8.0			323		27	37						
80	7/30	8.0			296									
81	7/31	7.8			434									
82	8/1	7.9			333									
84	8/3	7.5			344		16	38						
85	8/4	8.4			310		10							
87	8/6				344		131	43						
88	8/7				306									
89	8/8				405									
91	8/10													
92	8/11	6.2			340		51	42						
93	8/12	10.9			318		113	22						
94	8/13	8.0			300		36	15						
95	8/14	8.4			330		11	100						
96	8/15	9.4			360		9	89						
97	8/16	9.2			404	5424	20	30	5404					
98	8/17	8.7			200		14	50						
100	8/19	9.9			246		94	57						
101	8/20	10.9					137	34						
102	8/21	8.5			286		49	39						
103	8/22	7.4			257		93	29						
104	8/23	8.3			251		75	17						
105	8/24	8.8			354	4191	48	0	4143					
106	8/25				393									
108	8/27	8.2			202		26	34						
109	8/28	11.3			318		116	18						
110	8/29	8.8			311		10	40						

*Values Reported in mg/l.

Process Alternatives Considered & Preliminary Process Selection

The process alternatives considered and the preliminary selection are detailed by the following reports:

"Preliminary Laboratory and Inplant Studies"
July 20, 1971

"Study of Alternate Waste Water Collection and Treatment Systems" October 15, 1971

"Capital and Operating Cost Breakouts"
December 31, 1971.

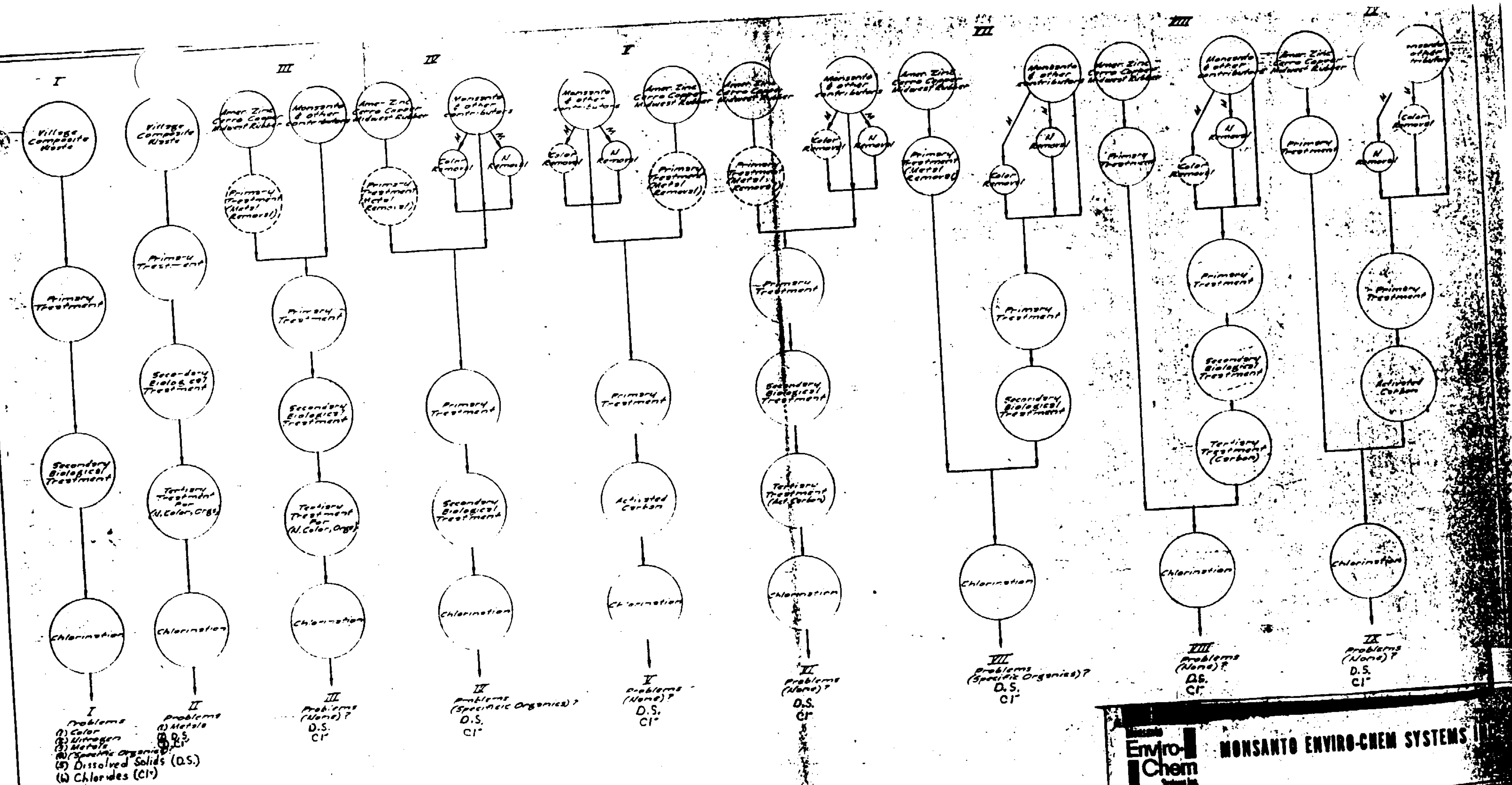
The pertinent sections of each of these reports have been included and are discussed individually.

"Preliminary Laboratory and Inplant Studies"

These studies were separated into two phases, a laboratory analytical program and bench scale investigations. The purpose of the analytical program was to define the problem, find which of the proposed effluent criteria were exceeded, and formulate a list of alternates to be considered. A list of nine process alternates was formulated (Dwg. X-103). These alternates formed the basis for the bench scale investigations which followed. The Summary of Results, Conclusions, and Recommendations for the Laboratory Analyses are included on pages 63-73.

The nine alternatives which formed the basis for the bench scale investigations are basically combinations of the following unit processes:

biotreatment
activated carbon
neutralization



Monsanto Enviro-Chem Systems Inc.

MONSANTO ENVIRO-CHEM SYSTEMS

ALTERNATIVE FLOW DIAGRAMS
WASTE WATER TREATMENT PLANT
FOR
VILLAGE OF SAUGET, ILLINOIS

	BY	DATE	APPROVED	DATE	JOB NO.
DRAWN	GWC	1/5/71	JLJ	1/71	022
CHECKED	[illegible]	1/71			DWG. NO. X
SCALE					

The reasoning behind the selection of alternates V and IX for pilot scale evaluation and the elimination of the other seven schemes were: (Basis - Proposed Standards Spring 1971)

<u>Scheme I</u>
(eliminated) The biological system showed a very low level of activity treating the effluent from a neutralization and sedimentation operation. Phenols, nitrogen or color were not reduced to acceptable levels. Metals removal was not acceptable.

<u>Scheme II</u>
(eliminated) Solving the problems with Scheme I by going to tertiary treatment would be more expensive than removing the contaminants at the source.

<u>Scheme III</u>
(eliminated) Metals can be removed at the sources by treating selected streams. Problems with biological and tertiary treatment are the same as mentioned above.

<u>Scheme IV</u>
(eliminated) It was not possible to determine the toxic constituents of the waste and thus impossible to synthesize a waste that could be treated biologically to any greater a degree than in the other treatment investigations.

<u>Scheme V</u> This scheme will be evaluated further during pilot plant operations and under separate contracts with individual industries.

<u>Scheme VI</u>
(eliminated) Problems with the biological system and expense for tertiary treatment.

Scheme VII
(eliminated) High expense for a segregated sewer system. Problems with biological treatment and removal of color at the source.

Scheme VIII
(eliminated) Same problems as for VII plus a high cost for tertiary treatment.

Scheme IX The high expense for a segregated sewer system may be an acceptable alternative in light of the recent Illinois Pollution Control Board Proposal which would require primary and secondary treatment for storm water in combined sewer systems. Several modifications of this scheme must be considered under a separate contract.

Schemes V and IX are shown in Figure 6.

Report of October 15, 1971
"Study of Alternate Waste Water Collection and Treatment Systems"

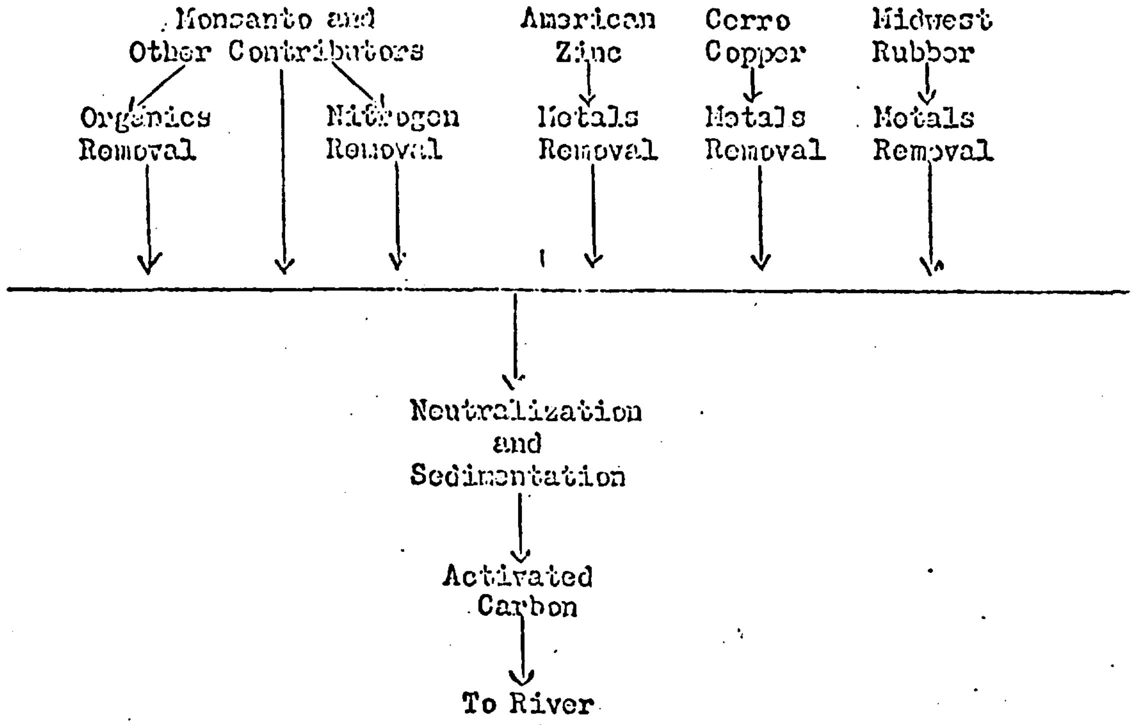
As alluded to in the discussion of Scheme IX above, the Pollution Control Board proposed a requirement of primary and secondary treatment for storm water in combined sewer systems. Because of this proposal a separate study was undertaken to determine if construction of a segregated sewer system could be justified. The four alternates considered in this report are shown in Figure 7 . The Summary, Recommendations, and Conclusions have been included on pages 74 through 81.

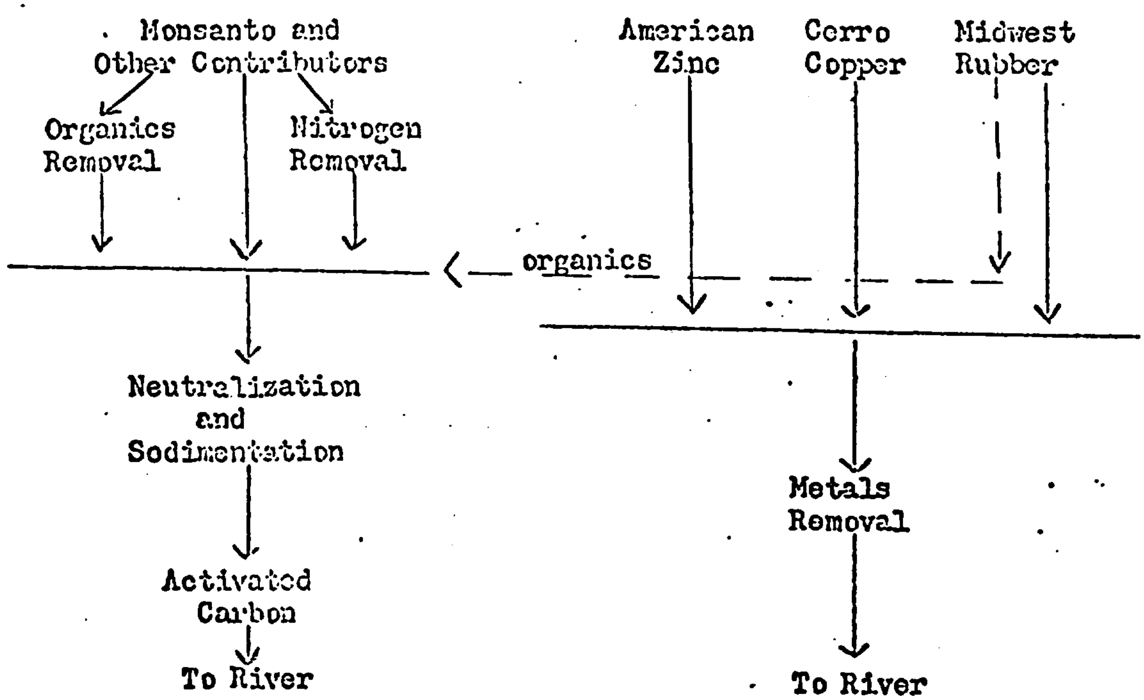
Report of December 31, 1971
"Capital and Operating Cost Breakouts"

No clear-cut decision was reached as to which alternate was feasible as a result of the October 15 report. After review of the report by the Village Sanitary Development and Research Association, more refined cost information was required for each industry to assess the various alternatives. As a result, capital and operating cost breakouts for each industry for seven cases of flow and contaminant reduction were requested. On 11/15/71 the State amended the requirement for primary and secondary treatment of storm

FIGURE 6

FEASIBLE SCHEMES FOR TREATMENT





water to a requirement of primary and secondary treatment for the "first flush": For this reason the base case for the capital and operating cost breakout study was chosen as shown in Drawing 372. By this time biological treatment had been eliminate as a viable method of treatment, thus the base case included activated carbon. During the time the alternate water collection survey and the capital and operating cost breakout studies were completed, the pilot plant evaluations were also completed on 11/17/71. The data which was accumulated during the pilot plant evaluations was used as a basis for the capital and operating cost study which was released on December 31, 1971. The cost figures, generated in the breakout study, were used to select the preliminary process to undergo process design and optimization. As can be seen from Table 16 activated carbon accounted for a substantial portion of the costs in all the cases evaluated. The unit operations involved with the carbon system were filtration; backwashing and pumping; the carbon columns; regeneration; and carbon makeup. These four operations accounted for 54, 55 and 50 percent of the costs in cases 1, 3 and 7 respectively. Carbon treatment was not recommended because of the technical problems with meeting a BOD_5 standard decreased carbon capacity, after regeneration more efficient removal of some organic contaminants at the source and extremely high capital and operating costs.

The preliminary process is shown on page 28. The process includes the following unit operations and/or equipment:

1. Screening
2. Pumping
3. Storm Water Storage
4. Storm Water Clarifier
5. Grit Removal
6. Neutralization
7. Flocculation
8. Scum Removal
9. Sludge Handling

Lab Analysis

SUMMARY OF RESULTS

The Village of Sauget waste was characterized during a two-month daily sampling program in the Fall of 1970. (Avg. flow ~24 MGD)

(1) Essentially all of the metals specified by the Illinois Pollution Control Board in their proposed criteria were present in the treatment plant effluent in concentrations in excess of the proposed criteria.

(2) Waste pH was between 2 and 3, far below proposed allowable level.

(3) Color producing organics (i.e., nitroanilines, nitrophenols, and 4 nitro diphenylamine produced an intense straw yellow to green color in the plant effluent. (APHA $>$500)

(4) Dissolved solids were present in the effluent in concentrations three to four times the level allowed under the proposed criteria.

(5) The total nitrogen content of the effluent was far in excess of the allowable limits.

(6) BOD_5 values averaged four times the allowable levels being proposed.

(7) Phenols were being discharged in levels 60 times above the proposed criterion.

(8) Suspended solids in the effluent fluctuated greatly and would not be in compliance.

Lab Analysis

RECOMMENDATIONS

Laboratory and bench scale studies should be conducted to determine the performance of various unit operations for removal of specific contaminants. The basic unit operations which will be investigated and alternative flow diagrams are indicated in Drawing X 103.

Lab Analysis

CONCLUSIONS

(1) Additional treatment either at the source or for the total Village effluent will be required to meet some of the proposed effluent criteria.

(2) Normal "secondary treatment" will probably not begin to reduce contaminants to levels proposed by the Pollution Control Board.

(3) Some of the proposed criteria such as dissolved solids and chlorides may not be possible to meet with available technology at a reasonable cost.

Lab And Bench Scale Experimentation

SUMMARY OF RESULTS

(1) Lime treatment of the effluent:

   (a) does not produce an effluent that will meet the proposed total heavy metals criterion of 2 mg/l;

   (b) does not produce an effluent that will meet the proposed requirements for specific metals such as copper, cadmium, and mercury;

   (c) does not remove a significant amount of BOD_5 or COD even at high dose rates - pH $\geq$11, concentration $\geq$1000 mg/l;

   (d) does not remove color or phenols to a significant extent.

(2) Batch studies of biological treatment were unsuccessful. Because of the low BOD_5 of the waste, the batch units were operating at a very low substrate level and essentially starving.

(3) Biological testing in continuously-fed units was also unsuccessful. BOD_5 of waste was very low and the system was essentially starving.

(4) Activated carbon treatment will remove color, phenols and certain nitrogen containing organics. Costs for this treatment are very high relative to normal biological treatment.

(5) A table showing the removals of various problem components has been shown. It should be noted that even with in-plant treatment for metals removal, followed by a treatment plant with a neutralization system, polyelectrolyte addition,

sedimentation and activated carbon treatment, that the effluent may still be in violation of certain heavy metals requirements, total heavy metals requirements, and nitrogen requirements. Dissolved solids will definitely be above the proposed criteria. Certain concentrated salt streams within various industries could possibly be treated but the technology and economics are very questionable.

(6) The two treatment schemes which appear technically feasible from the list of nine evaluated have been shown on page 62.

The second alternative, which would have required a new sewer system, appeared to be far too expensive to consider. Complete treatment of the metal-bearing wastes at one central site would have been advantageous as far as realizing the economy of scale but this savings may be lost when comparing treatment at each plant and eliminating clean cooling water streams. This is particularly true for Midwest Rubber.

With a change in the proposed criteria requiring primary and secondary treatment of storm waters, several additional flow schemes similar to this one involving sewer segregation may be attractive alternatives. Before the change in the ruling, storm water in excess of the design flow could be bypassed after primary treatment. With the new alternatives to either treat this storm water at peak flow or impound the water and bleed it back into the treatment system at a controlled rate, the most economical solution may be to put in a clean water sewer system and discharge clean cooling waters plus clean treated waste waters. This clean water sewer could possibly reduce the flow requiring treatment at the Village Treatment Plant to 12 MGD.

<u>Lab and Bench Scale Experimentation</u> (cont'd)

A proposal for the additional investigation work has been submitted to the Village.

(7) Pilot plant operations now include a lime neutralization step followed by an activated carbon system and a biological system operating in parallel.

Alternate Waste Water Collection & Treatment Systems

SUMMARY

Because of the proposal requiring both primary and secondary treatment for storm water in combined sewer systems, it was thought that construction of a segregated sewer system might be justified for the Village of Sauget, Illinois. The Village assigned the task of evaluating various segregation alternatives and comparing their costs with those for the combined sewer system to Monsanto Enviro-Chem Systems, Inc. of Chicago. This particular study commenced during the first part of August, 1971. Monsanto Enviro-Chem had been conducting flow measurement studies, flocculation studies, in-plant studies laboratory studies, treatment scheme evaluations, pilot plant work and preliminary process design since August, 1970 at a cost to the Village of Sauget and private industry of about $200,000.

The unit operations included in the treatment scheme being investigated in the pilot plant include screening, grit removal, neutralization, flocculation, sulfide addition, sedimentation, filtration, and carbon adsorption.

The four alternatives considered for this study have beed described in the Summary Table. The treatment plant involves the same unit operations for each case but varies in capacity from 14.85 MGD to 29.5 MGD.

The capital cost figures for the various alternatives presented should be considered rough engineering estimates with an accuracy no greater than plus or minus 35%. If one were to rank the estimates as to accuracy then the estimates for Alternatives IA & IB should be considered more accurate than II & III because of the many unknown factors involved in the inplant and Village modifications required for II & III.

The estimated capital costs for the various Alternatives are shown in the Summary Table.

Direct operating costs were calculated and several financing cases considered which would yield different indirects or amortization rates. One case involved 15 year General Obligation bonds (5½%), 30 year Revenue Bonds (6%) and private capital depreciated over 10 years. Another case involved private capital depreciated over a 10 year period. The total operating costs are also shown in the Summary Table.

Because of the limits of accuracy for the various estimates it is not possible to adequately differentiate between the alternatives on an initial cost basis. Operating costs are also very comparable for the different alternatives because the major direct operating costs do not change.

Essentially the same amount of acid must be neutralized for each case as well as the same amount of organic contamination removed by the carbon.

Various factors were considered before making any recommendations:

(1) No standards now exist for storm water sewers so that there is no way of being certain how much water would be acceptable for such a system.

(2) The cost estimates for Alternatives IA & IB are undoubtedly more accurate than those for Alternatives II & III.

(3) Revisions in the segregation plan for Alternative II could produce a capital cost comparable to that for III.

(4) More expansion capacity as far as utilization of storm water capacity for process flows and increasing storage capacity would be available for Alternative IB compared to II & III.

(5) Alternatives II & III would provide "new sewers" and offer better control of waste streams.

(6) One alternative may be very favorable to one or more of the industries but not the best solution for the Village as a whole. This would lead to some industries wanting their own segregation and treatment system with sewers bypassing the treatment plant.

(7) In order for each industry to decide which Alternative would best solve their problems, a detailed breakout of costs would be required. This was beyond the scope of this report.

(8) Perhaps construction of privately financed treatment plants should be given more thought.

With these thoughts considered, the following recommendations were made:

(1) More study work in the form of detailed design would be required to improve cost estimates.

(2) If more engineering study work is not done, Alternative IA or IB would be the safest economic choice. The final decision between the two, of course, will depend on the Pollution Control Board's rulings.

(3) If further study work is authorized, then a preliminary rate schedule and cost breakouts for the individual industries and the Village will be required to give all concerned enough information to make a decision.

If one of the alternatives involving construction of segregated sewers is recommended and finally selected by the Village, additional experimental and design work will be required for the treatment plant as well as a great deal of additional engineering work required for inplant modifications. This will definitely prevent meeting the proposed schedule in the Variance Petition (September, 1971). Even if Alternative I which involves minor sewer and inplant changes is chosen, there will have been a certain amount of time lost in the decision making process, thus possibly preventing compliance with the schedule in the Variance Petition.

TABLE 15

Alternate Waste Water Collection & Treatment Systems

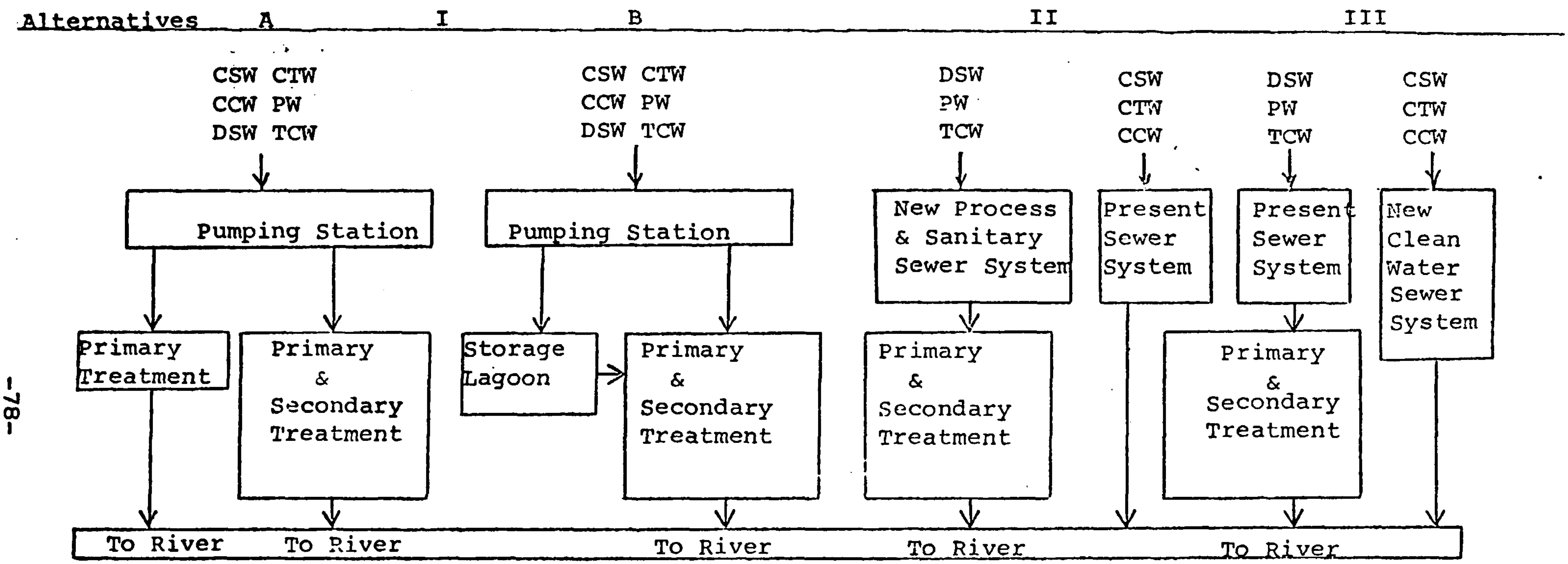
SUMMARY TABLE

Alternative	Description	Sewer System	Inplant & Village Modifications	Treatment Plant	Capital Cost	TOTAL OPERATING COSTS: G.O. & Revenue Bonds + Private Capital ¢/1000 gal	TOTAL OPERATING COSTS: G.O. & Revenue Bonds + Private Capital *$/Yr.	TOTAL OPERATING COSTS: Private Capital ¢/1000 gal.	TOTAL OPERATING COSTS: Private Capital $/Yr.
IA	Primary Treatment for Storm Water and Secondary for Normal Flow	Combined (Existing System)	Minor	23.5 MGD	$13,400,000	49.4	4,250,000	53.2	4,550,000
IB	Primary & Secondary Treatment For Storm Water and Normal Flow	Combined (Existing System)	Minor	29.5 MGD	14,700,000	42.4	4,570,000	45.8	4,940,000
II	Primary & Secondary Treatment For Process, Sanitary & a Portion of the Storm Water	Segregated (New Process Sewer)	Major	14.85 MGD	11,500,000 (Treatment Plant) 5,000,000 (Village & Industries) 16,500,000	79.7	4,320,000	91.0	4,940,000
III	Primary & Secondary Treatment For Process, Sanitary & a Portion of the Storm Water	Segregated (New Storm Sewer)	Major	14.85 MGD	11,100,000 (Treatment Plant) 2,800,000 (Village & Industries) 13,900,000	77.6	4,200,000	86.8	4,700,000

*First 10 Years

Alternate Waste Water Collection & Treatment Systems

FIGURE 7
ALTERNATIVE TREATMENT SCHEMES



LEGEND

Clean Water Sewer - (no further treatment required)

CSW - Clean Storm Water

CTS - Clean Treated Water

CCW - Clean Cooling Water

Contaminated Water Sewer-(further treatment required)

PW - Process waste water & sanitary

DSW - Dirty Storm Water

TCW - Treated Contaminated Water

CONCLUSIONS AND RECOMMENDATIONS

Because of the limits of accuracy for the various estimates, it is not possible to adequately differentiate between the alternatives on an initial cost basis. Operating costs are also very comparable for the different alternatives because the major direct operating costs do not change from one alternative to the other. Essentially the same amount of acid must be neutralized for each case as well as the same amount of organic contamination removed by the carbon.

One should, however, keep several thoughts in mind when judging the alternatives:

(1) There is no guarantee that water that has been assumed to be uncontaminated process and storm water actually will meet criteria not yet established or proposed by the State.

(2) Capital costs for Alternative II would probably be much closer to that for Alternative III if an underground tile sewer had been assumed for II instead of the overhead lines and sumps or if a detailed study had been conducted to determine costs associated with working around underground obstructions.

(3) The cost estimates for Alternatives IA and IB are undoubtedly more accurate because they only required design and cost estimates for the treatment plant. The work for Alternatives II and III involved design of segregation and treatment stystems within each plant as well as Village sewer modifications. It is our feeling that our estimate for this inplant work and sewer work is probably low. A much more detailed study involving representatives from each industry in the design details would be required to provide a more accurate estimate.

(4) If Alternative II or III were chosen, design and construction within plants and the Village sewer modifications would probably prevent

meeting the Village's proposed date for treatment plant start-up. More experimental work would also be required to design the treatment plant for half the flow and twice the pollutant concentration.

(5) Alternatives II and III would reduce the amount of flooding and would also offer "new sewers".

(6) Alternatives II and III would offer better control of wastes and an incentive to segregate where ever possible.

(7) Expansion capacity would be available for industrial expansion for Alternatives IB, II, and III. With the excess flow capacity the storage lagoons could be enlarged to store storm water for a longer period of time and a portion of the flow capacity could then be utilized for industrial flow. Alternative IB would have more capacity available - $<$9.4 cfs for IB and $<$ 4 cfs for II and III.

(8) One alternative may be very favorable to one or more of the Village industries but not the best solution for the entire Village.

(9) Perhaps an inplant segregation system and bypass of the Village treatment plant should be considered by one or none of the industries even if the Village decides not to construct a segregated system.

(10) In order for each industry to decide which alternative will best solve their individual problems, a detailed breakout of costs may be required. This is beyond the scope of this report.

(11) Perhaps one or more of the Village industries should consider constructing a privately run treatment plant.

With the above mentioned thoughts considered, we will make the following recommendations:

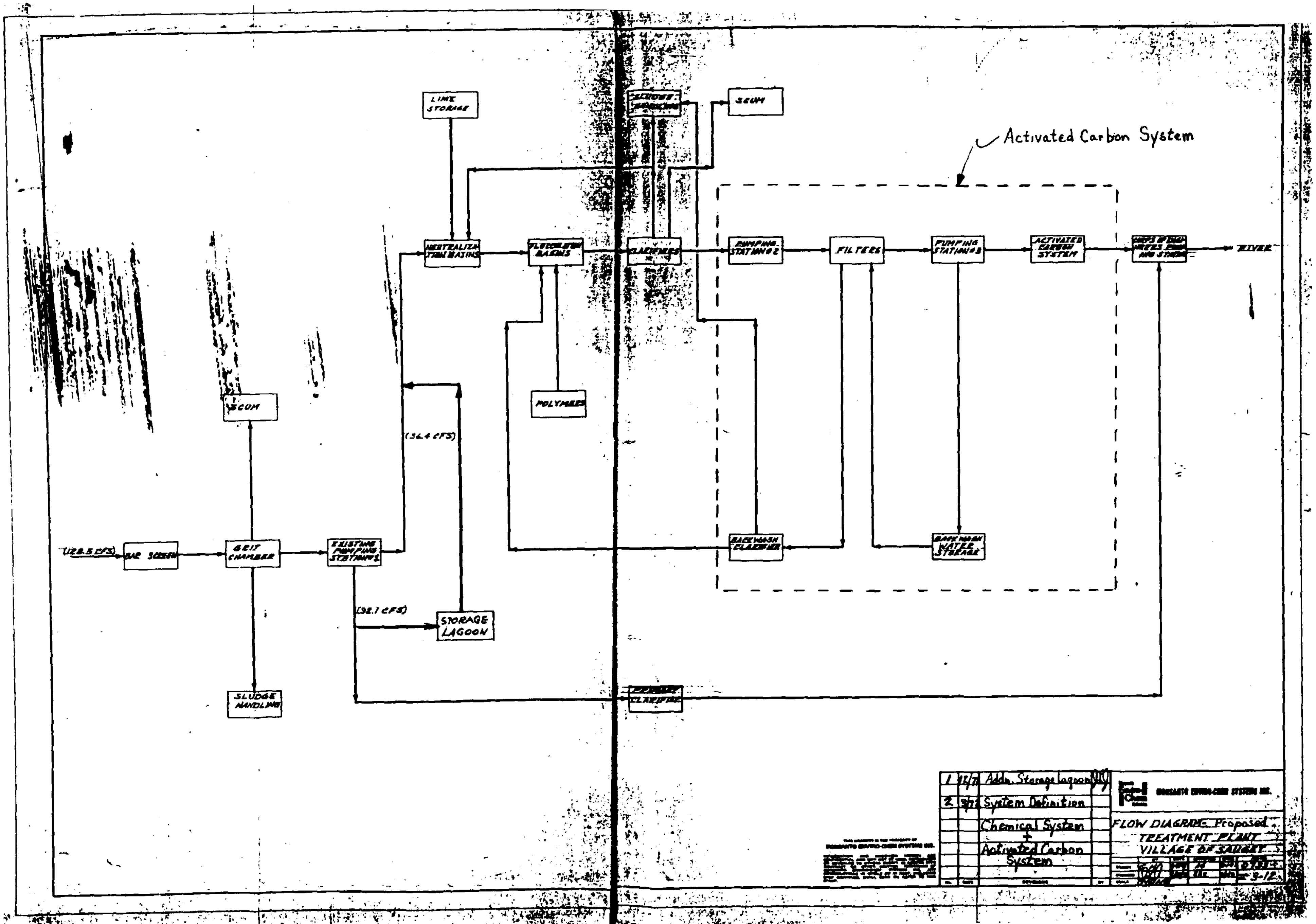
(1) More study work in the form of detailed engineering design is required to improve cost estimates.

(2) If the Village decides not to have further study work done, then Alternative IA or IB should be chosen depending on state legislation. This would be the safest economic choice without further evaluation.

(3) If further study work is done, the following questions must be answered:

   (a) What is the best solution for each individual industry?

   (b) What is the best solution for the Village?



Activated Carbon System
(128.5 CFS)
BAR SCREEN
GRIT CHAMBER
SCUM
SLUDGE HANDLING
EXISTING PUMPING STATION #1
(32.1 CFS)
(36.4 CFS)
STORAGE LAGOON
LIME STORAGE
NEUTRALIZATION BASINS
FLOCCULATION BASINS
POLYMERS
CLARIFIERS
SCUM
PUMPING STATION #2
FILTERS
PUMPING STATION #3
ACTIVATED CARBON SYSTEM
BACKWASH CLARIFIER
BACKWASH WATER STORAGE
PRIMARY CLARIFIER
RIVER
1 Addn. Storage Lagoon
2 System Definition
Chemical System + Activated Carbon System
MONSANTO ENVIRO-CHEM SYSTEMS INC.
FLOW DIAGRAM Proposed TREATMENT PLANT VILLAGE OF SAUGET

Capital & Operating Cost Breakouts

SUMMARY

This report presents breakouts of the capital and operating cost estimates by industry and the Village for the Village of Sauget, Illinois. Costs have been worked out for seven separate cases involving flow reductions, soluble COD reductions and acidity reductions.

Estimated total capital and operating cost contributions for each waste contributor have been listed in summary Tables 16 and 17.

Capital & Operating Cost Breakouts

TABLE 16

SUMMARY OF CAPITAL COST BREAKDOWN*
(CASES 1 thru 7)
INDIVIDUAL CONTRIBUTORS

	Case No.		1	2	3	4	5	6	7
	SOURCE								
1.	American Metals Climax	A=	2,534	0	362	396	396	437	439
		B=	1,341	0	223	243	243	269	271
2.	Edwin Cooper	A=	1,393	1,535	1,513	1,072	908	1,004	1,012
		B=	589	676	660	410	410	454	461
3.	Cerro Corp.	A=	935	1,072	1,052	849	849	948	949
		B=	511	593	578	475	475	532	533
4.	Midwest Rubber Reclaiming Co.	A=	393	425	412	428	316	349	349
		B=	116	142	132	142	142	156	156
5.	Monsanto Ind. Chem. Co.	A=	7,312	8,144	7,986	7,748	7,490	6,032	6,021
		B=	3,197	3,701	3,589	3,528	3,528	2,993	2,982
6.	Village of Sauget	A=	40	49	50	51	51	57	58
		B=	22	26	26	27	27	30	32
	TOTALS	A=	$12,607	$11,224	$11,374	$10,544	$10,011	$ 8,827	$8,827
		B=	$ 5,776	$ 5,138	$ 5,209	$ 4,825	$ 4,825	$ 4,434	$4,435

A=Total Proposed Treatment System (Including Carbon)
B=Chemical Treatment System (Without Carbon)

*All costs expressed thousands of dollars

Capital & Operating Cost Breakouts

TABLE 17*

Capital Costs (Cases 1 through 7) Village Treatment Facility

		CASES 1	2	3	4	5	6	7
	Unit Operation Basis (Flows)	23.88 MGD Alt IA	17.67	18.32	14.92	14.92	11.72	11.
I	Scr. & Lag. A=Scr. & Lag. (Flow) B=Prim. Basin	A 114 B 190	A 114 B 190	A 114 B 190	A 114 B 190	A 114 B 190	A 114 B 190	A 1 B 1
II	Grit Chamber (Pumping) (Flow)	298	249	254	225	225	195	1
III	Neutr. Coag, Floc., (Lime, no NaHS) (Flow)	1,007	841	859	759	759	658	6
IV	Lime Storage Handling, Control (Acidity)	391	391	391	391	391	391	3
V	Clarification (Flow)	2,565	2,142	2,188	1,934	1,934	1,675	1,6
VI	Filtration Back-wash, Pumping (Flow)	2,009	1,678	1,714	1,515	1,515	1,312	1,3
VII	Carbon Cols. (Flow)	2,508	2,094	2,139	1,891	1,891	1,638	1,6
VIII	Regeneration (COD)	1,816	1,816	1,816	1,816	1,442	1,195	1,1
IX	Carbon Make-up (COD)	498	498	498	498	339	248	2
X	Sludge Handling (Solids)	1,211	1,211	1,211	1,211	1,211	1,211	1,2
	Totals	$12,607	$11,224	$11,374	$10,544	$10,011	$8,827	$8,
	Chemical System Only	$ 5,704	$ 5,138	$ 5,207	$ 4,824	$ 4,824	$4,434	$4,4

*All costs expressed in thousands of dollars

Proposed Integration of Present Facility Into Recommended Process Design

The integration of the present facility into the recommended process design is shown by the preliminary plot plan (page 33). The existing trash screens and the pumping station should be used with modification. The storm water storage lagoon and the storm water clarifier will be new. The present parshall flume should be used.

The present clarifiers should be used with some modifications to the rake mechanism and possibly to the sludge collection system. Flocculation chambers should be built in the front end of both clarifiers. The existing scum handling facilities should be used with modifications. The neutralization system including the lime slakers, the lime silos and the neutralization tanks should be located roughly as shown. The sludge handling facilities will require a new, separate structure. All major controls to the plant should be included in the present operations building with some modifications.

GRANT POSSIBILITIES

Construction Grants

Because the controversy concerning the House of Representatives' Bill 11896 and the Senate's Bill 2770 has not been resolved, and may not be settled until after November, 1972, it is impossible to predict the probability of Sauget receiving construction grant assistance. It is also impossible to predict the conditions under which such a grant would be given, but some conditions which are common to both bills require the applicant to:

(1) Be part of regional plan.

(2) Conform with state plans and requirements.

(3) Have been given a priority by the state for receiving funds.

(4) Have plans for paying non-federal share and operate plant properly under a state plan.

(5) Have sufficient reserve capacity.

(6) Assure that no specifications for bids contain proprietary, exclusionary or discriminatory requirements unless necessary for demonstration or operation.

(7) Provide that each user of facility pay his proportionate share of operating cost.

(8) Provide for repayment by industrial users of their fair share of construction costs attributable to the federal share of construction costs.

(9) Have adequate plans and financial capabilities to construct and operate such works.

The filing deadline for grants for the State of Illinois for the fiscal year 1973 has already passed; the deadline was April 30, 1972. Little if any benefits, however, would have been derived from hurriedly putting together a request to meet this deadline. A higher priority rating will be possible when engineering and financial details are more firmly established.

Filing for fiscal year 1974 can be done after completion of detailed design of the chemical treatment system but work should commence as soon as possible because of the amount of time required for preparation of a complete package.

The fund distribution priority will be based on a number of factors:

I Water Pollution Control Factor - Severity of problem and to what extent proposed facility will alleviate the problem.

II Project Readiness Factor - Based on design data available, status of financing plans, site acquisition, plans and specifications.

III Community Prevention and Control Factor - Comprehensive engineering report, public relations, sewer use ordinance, sewage treatment works operation and maintenance, certification of operators, area annexation.

IV Financial Need Factor - Communities assessed valuation per capita and cost of proposed improvements per capita.

V Relative Water Quality Improvement

The amount of construction costs covered by grants varies in the two bills with the minimum being the Senate version, 70% federal and 10% state, and the maximum 75% federal and 15% state under the House version. The old act stipulated 50% federal and 25% by the state.

All applications for construction grants must go to the Facilities Certification Section, Division of Water Pollution Control, Illinois Environmental Protection Agency, 2200 Churchill Road, Springfield, Illinois 62706. Application forms may be obtained from the above office.

GRANT ASSISTANCE PROGRAMS OF THE FEDERAL EPA

Water Pollution Control Research Development and Demonstration Grants

Grants for advanced waste treatment, joint municipal industrial treatment, and projects involving storm and combined sewer projects may be made only to states, municipalities, and interstate and intermunicipal agencies.

For projects relating to prevention of pollution of waters by industry, grant may not exceed $1 million or 70% of project cost. Other grants may not exceed 95% of the estimated project cost.

Unless some new advanced waste treatment technology after chemical treatment, or joint treatment with E. St. Louis is undertaken, the chances for this type of grant appear slim.

If advanced waste treatment technology is employed within any of the contributing industries which could be considered research and development of new technology, then an application for Federal funds would be advisable.

APPENDIX I

RAW WASTE CHARACTERISTICS

1. Present Treatment Plant Operations Report Data Summary
2. Flow Analysis
3. Raw Waste Characteristics (Pilot Plant Master Data Tables)
4. Raw Waste Characteristics Summary

FLOW VARIATION ANALYSES

DISCUSSION

In order to determine if dry weather flow peaking in the Village sewers would require any design accommodations, daily flow data from the treatment plant were analyzed. The date, day of the week, daily flow total, peak flow, duration of peak, and the time of occurrence as well as any precipitation data were noted, Table 19. Data was analyzed for June, July and August of 1971. The data is summarized in Table 18.

TABLE 18

PEAK FLOW SUMMARY

Date	Day	Time	Duration	Peak (MGD)	Precipitation	Time
6/3/71	Thurs.	3:15 PM	15 min.	32	None	
6/10/71	Thurs.	11:40 AM	4 hrs.	35	0.50"	10-11 AM
6/11/71	Fri.	4:45 PM	3.75 hrs.	35	1.0"	3-5 PM
6/30/71	Wed.	11:00 AM	15 min.	32	None	
7/2/71	Fri.	8:00 AM	6 hrs.	24	None	
7/6/71	Tues.	10:30 AM	15 min.	22	None	
7/18/71	Sun.	9:30 AM	2 hrs.	30	0.49"	7-8 AM
7/19/71	Mon.	9:30 AM	5 min.	27	Trac	12-1 AM
8/11/71	Wed.	9:45 AM	3.75 hrs.	19	0.94	12-1 AM
8/12/71	Thurs.	10:00 AM	5 hrs.	19	None	
8/17/71	Tues.	5:00 PM	14 hrs.	20	None	
8/18/71	Wed.	9:45 AM	20 min.	29	None	
8/24/71	Tues.	2:00 AM	6 hrs.	20	None	

TABLE 19 - PEAK FLOW ANALYSIS

Date	Daily Total MGD	Peak MGD	Duration Hours	Time	Precipitation	
6/1/71	21.5	23	I	R	T	
6/2/71	22.5	23	I	R	0.36	
6/3/71	22.5	32	15 min.	3:15 PM		
6/4/71	22.5	23	I	R		
6/5/71	22.5	23	I	R		
6/6/71	15.0	23	I	R		
6/7/71	19.5	23	I	R	0.20	
6/8/71	21.0	23	I	R		
6/9/71	21.0	23	I	R		
6/10/71	25.5	35	4	11:40 AM	.50	10-11 AM
6/11/71	22.5	35	3.75	4:45 PM	1.00	3-5 PM
6/12/71	26.0	23	I	R	0.02	
6/13/71*	24.5	23	I	R	0.15	
6/14/71	19.5	23	I	R	0.01	
6/15/71	20.0	23	I	R	T	
6/16/71	20.0	21	I	R		
6/17/71	20.0	22	I	R		
6/18/71	20.0	21	I	R		
6/19/71	19.0	22	I	R		
6/20/71	19.0	21	I	R	T	
6/21/71	20.0	22	I	R	0.18	
6/22/71	20.0	29	I	R		
6/23/71	20.0	29	I	R	T	
6/24/71	20.0	24	I	R		
6/25/71	20.0	22	I	R		
6/26/71	20.0	22	I	R		
6/27/71	15.0	N.C.				
6/28/71	20.0	N.C.				
6/29/71	20.0	25	I	R	0.01	
6/30/71	20.0	32	15 min.	11:00 AM		

*Daily total greater than peak due to improper flume calibration

Note

R = Random
I = Intermittent
NC = No Chart
T = Trace

TABLE 19 - PEAK FLOW ANALYSIS

Date	Daily Total MGD	Peak MGD	Duration Hours	Time	Precipitation
7/1/71	20	24	I	R	
7/2/71	20	24		8 AM - R	
7/3/71*	20	20	I	R	
7/4/71*	18	34	15 min.	10:30 PM	1.02 7-10 PM
7/5/71*	18	22	I	R	
7/6/71*	20	22	15 min.	10:30 AM	
7/7/71*	20	15	I	R	
7/8/71*	20	19	I	R	
7/9/71*	20	20	I	R	T
7/10/71*	16	19	I	R	.95
7/11/71*	16	9	Continuous		T
7/12/71*	16	17	I	R	
7/13/71	18	19	I	R	.04
7/14/71	18	30	1	8 AM	.72
7/15/71	18	18	Continuous		T
7/16/71	18	18	Continuous		
7/17/71*	21	18	Continuous		
7/18/71	21	30	2	9:30 AM	.70 7-8 AM
7/19/71*	21	27	5 min.	9:30 AM	T
7/20/71*	20	18	I	R	
7/21/71*	21	17	I	R	
7/22/71*	23	17	I	R	
7/23/71*	22	19	I	R	.67
7/24/71*	22	19	I	R	
7/25/71	22	N.C.			
7/26/71	19	N.C.			
7/27/71	19	N.C.			
7/28/71	19	N.C.			.30
7/29/71	14	N.C.			.30
7/30/71	12.5	19	I	R	T
7/31/71	14	19	I	R	

*Daily total greater than peak due to improper flume calibration

Note ·

R = Random
I = Intermittent
NC = No Chart
T = Trace

TABLE 19 - PEAK FLOW ANALYSIS

Date	Daily Total MGD	Peak MGD	Duration Hours	Time	Precipitation
8/1/71*	18	21	Continuous		
8/2/71	18	19	Continuous		
8/3/71	18	19	Continuous		
8/4/71	17.5	19	I	R	
8/5/71	13.5	19	I	R	
8/6/71	13.5	18	I	R	T
8/7/71	13.0	18	I	R	
8/8/71	9.9	18	I	R	
8/9/71	15	19	I	R	
8/10/71	15.4	19	I	R	T
8/11/71	15.5	19	3.25	9:45 AM	.04
8/12/71	15.7	19	5	10:00 AM	
8/13/71	16.4	N.C.			
8/14/71	14.0	19	I	R	T
8/15/71	8.0	15	I	R	
8/16/71	13.9	19	I	R	
8/17/71	17.8	20	14 hrs	5:00 PM	
8/18/71	19.5	29	20 min.	9:45 AM	
8/19/71	13.8	19	I	R	
8/20/71	13.8	19	I	R	
8/21/71	11.5	19	I	R	.04
8/22/71	13.1	17	I	R	
8/23/71	13.5	18	I	R	
8/24/71	13.2	20	6	2:00 AM	
8/25/71	16.5	19	I	R	T
8/26/71	16.9	19	I	R	
8/27/71	14.6	19	I	R	
8/28/71	14.2	17	I	R	
8/29/71	12.1	17	I	R	
8/30/71	15.8	20	I	R	
8/31/71	17.2	20	10	9:30 PM	

*Daily total greater than peak due to improper flume calibration

Note

R = Random
I = Intermittent
NC = No Chart
T = Trace

TABLE 20

SAUGET SEWAGE TREATMENT PLANT DATA
Summary for 1971

Month	Flow MGD	Suspended Solids mg/l	COD mg/l	Phenol mg/l	Acidity mg/l
January	21	79	430	6.5	412
February	22	93	432	6.8	449
March	24	57	409	6.4	549
April	23	55	404	5.0	485
May	21	70	401	5.6	560
June	20.6	62	487	5.3	762
July	18.9	82	427	5.1	823
August	14.5	81	553	10.1	1087
September	13.5	90	477	6.8	1336
October	13.0	139	530	7.5	1375
November	12.0	77	559	8.9	1196
December	13.0	83	387	8.6	959
Average	18.0	81	458	6.4	833

TABLE 21

MASTER DATA TABLE (RAW WASTE)

Day No.	Date	pH	Temp. (°F)	BOD $_5$*	COD*	Total Solids*	Susp. Solids*	% Volatiles	Dissolv. Solids*	Phenols*	Free Chlorine*	Total Chlorine*	Phosphate*	Color (APHA)
1	5/11	3.5	75		372									300
2	5/12	3.7	74		250		15	100		3.6	<.01	<.01		300
3	5/13	6.4	79		452		200	38			<.01	<.01		400
4	5/14	3.2	80		426		104	54			<.01	<.01		400
5	5/15	3.1	76		328		60	77			<.01	<.01		400
6	5/16	6.2	76		284		80	34			<.01	<.01		300
7	5/17	7.3	78		397	4240	394	15	3846	3.5	<.01	<.01		500
8	5/18	2.5	78		337		44	5			.11	.69		>500
9	5/19	2.6	76		455		54	7			<.01	<.01		>500
10	5/20	2.3	76		574		80	35		7.0				>500
11	5/21	2.2	76		476	3211	30	53	3158		<.01	<.01		>500
12	5/22	2.2	78		425		20	80			<.01	<.01		>500
13	5/23	2.4	62								<.01	<.01		>500
14	5/24				365									
15	5/25	2.3	76	80	394		30	60						
16	5/26	2.3	78	50	450		48	75						
17	5/27													
18	5/28	2.2												
19	5/29	2.3			736		147	84						500
20	5/30	2.7		105	476		60	45						>500
21	5/31	2.1	76	44	400		20	80						350
22	6/1	1.8	76	26	538		20	33			<.01	<.01		400
23	6/2	2.2	78	95	>650		77	49						>500

*Values Reported in mg/l.

TABLE 21

MASTER DATA TABLE (RAW WASTE)

Day No.	Date	pH	Temp. (°F)	BOD_5*	COD*	Total Solids*	Susp. Solids*	% Volatiles	Dissolv. Solids*	Phenols*	Free Chlorine*	Total Chlorine*	Phosphate*	Color (APHA)
24	6/3													
25	6/4	2.3	79	180	1630		174	80						>500
26	6/5	2.3	79	225	612		74	72						>500
27	6/6	2.1	79	135	408		30	73						>500
28	6/7	3.3	78	88	405	3379	21	57	3358					>500
29	6/8	2.1	82	120	410		22	73						>500
30	6/9	2.0	82	260	347		21	95						>500
31	6/10	1.9		333	648		200	68						>500
32	6/11		84								1.0	8		
33	6/12	2.1	83		560		124	60			<.01	<.01		>500
34	6/13	2.0	84	50	456		42	74			<.01	<.01		>500
35	6/14	2.2	80	80	593		32	81						>500
36	6/15													
37	6/16													
38	6/17	1.9			413		62	79						
39	6/18	2.0		140	434	2917	109	70	2816		<.01	<.01		>500
43	6/22				292		13	15						300
44	6/23	1.8			548		62	84						500
45	6/24	2.0	84	64	715		121	85						>500
46	6/25	1.8	84		560	2409	101	92	2308					>500
47	6/26	1.8	83		530		48	100						>500
48	6/27	1.7			514									>500
49	6/28	1.9			428		20	36						>500

*Values Reported in mg/l.

TABLE 21

MASTER DATA TABLE (RAW WASTE)

Day No.	Date	pH	Temp. (°F)	BOD_5*	COD_5*	Total Solids*	Susp. Solids*	% Volatiles	Dissolv. Solids*	Phenols*	Free Chlorine*	Total Chlorine*	Phosphate*	Color (APHA)
50	6/29				372		8	13						450
51	6/30	1.8			386									450
52	7/1	2.3		360	528		461	94						>500
53	7/2	1.9	77	245	377		28	75						>500
54	7/3	1.7	78		459		22	64						>500
55	7/4	[illegible]	64		404									>500
56	7/5	1.9	82		342									>500
57	7/6	1.6	82	150	354									>500
58	7/7	1.9		67	320									
59	7/8	2.1		328	578									>500
60	7/9	2.2		168	572									
61	7/10	2.8		57	410									
62	7/11	2.1			506									
63	7/12	1.6		100	335									
64	7/13	1.7		20	433									
65	7/14	1.9		100	456									500
66	7/15	1.9		54	445									>500
67	7/16			110	418									
69	7/19				506									
70	7/20				380									
71	7/21	1.6			430									
72	7/22													
73	7/23				638									

*Values Reported in mg/l.

TABLE 21

MASTER DATA TABLE (RAW WASTE)

Day No.	Date	pH	Temp. (°F)	BOD_5*	COD*	Total Solids*	Susp. Solids*	% Volatiles	Dissolv. Solids*	Phenols*	Free Chlorine*	Total Chlorine*	Phosphate*	Color (APHA)
74	7/24				394									
75	7/25				454									
76	7/26	1.8			490		46	48						
77	7/27	1.5			429		28	47						
78	7/28	2.1			560		85	93						
79	7/29	2.0			555		119	89						
80	7/30	2.0			568									
81	7/31	1.6			600									
82	8/1	1.9			435									
84	8/3	1.8			434		30	77						
85	8/4	1.6			411									
87	8/6				456		168	99						
88	8/7				503									
89	8/8				536									
92	8/11	2.3			352		78	63						
94	8/13	1.7			512		40	36						
95	8/14	1.5			460		30	100						
96	8/15	1.5			2260		89	99						
97	8/16	1.5			565	3163	85	100	3078					
98	8/17	1.3			503		24	75						
100	8/19	1.5			615		59							
102	8/21	2.2			406		36	50						
103	8/22	1.7			384		50	60						
104	8/23	1.5			533									
105	8/24	1.6			445	2441	53	64	2377					
106	8/25				397									
109	8/28	2.0			385		23	91						
110	8/29	1.8			379		9	89						

*Values Reported in mg/l.

APPENDIX II

NEUTRALIZATION REQUIREMENTS

A. ACIDITY

B. METALS REMOVAL WITH LIME

ACIDITY

During the pilot plant studies conducted for the Village of Sauget, one of the major waste treatment problems encountered was the waste's acidity and its neutralization. Table 22 shows a summary of the present and projected waste stream acidities. The present (1971) waste acidity was calculated by five methods using independent acidity measurements.

For method one, two acidity values were calculated from Village treatment plant acidity data collected during the pilot plant studies. The first value was from the period before American Zinc's shutdown and the second value from the period after the shutdown.

Method two used the contributor material balances (making allowances for all alkaline dumps and background raw water alkalinities), showing values with and without the American Zinc effluent.

Method three substituted measured values where available for each contributor in the method two calculations.

Method four used average daily pilot plant lime use rates for the periods indicated.

Method five used three characteristic pH titration curves. From these three curves the average total effluent acidity was plotted versus pH to yield the curve shown in Figure .

The waste stream acidity and flow rate were then monitored continuously for eleven days. Taking pH and flow readings every four hours during the period, the waste's acidity was determined (using Figure 8). The values shown in Table 22 show acidities calculated from these curves for four cases.

The final (sixth) method for calculating the waste stream acidity was from the letters submitted by each industry projecting their expected 1974+ average and maximum acidities.

TABLE 22

SAUGET WASTEWATER ACIDITY* CALCULATIONS

	METHOD 1 Present Treatment Plant Flow and Acidity Data	METHOD 2 Present Contributor Material Balances	METHOD 3 Present Contributor Material Balances + Measurements Where available	METHOD 4 Sauget Pilot Plant Lime Use Data	METHOD 5 Present pH Measurement and Titration Curves	METHOD 6 Projected 1974+ Waste Stream Compostion
Average values from 5/13-5/31/71 (19 Observations) Before American Zinc Shut-down	95,000	273,000	268,000	331,000		
Average values from 6/1-9/28/71 (120 Observations) After American Zinc Shut-down	138,000	243,000	252,000	278,000		
Average of all values measured using totalizer flow rates					765,000	
Average of all values measured using instantaneous flow rates					774,000	
Average, eliminating all acidities from pH's below 1.2, using totalizer flow rates					473,000	
Average, eliminating all acidities from pH's below 1.2, using instantaneous flow rates					438,000	
Average effluent						100,500
Backgrounds Deducted						92,400
Maximum Expected						426,000

*All acidities are expressed in lb/day of $CaCO_3$.

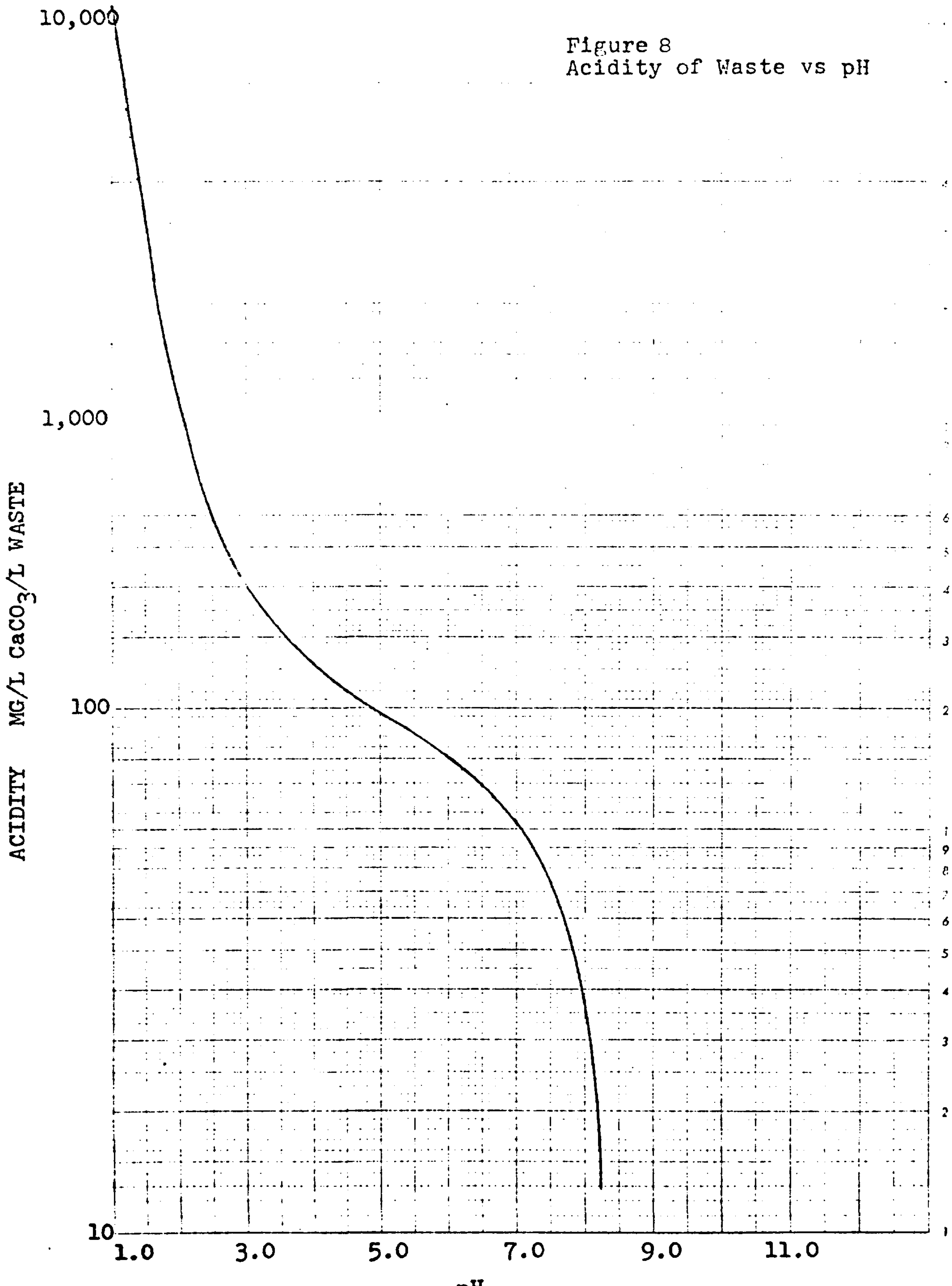


Figure 8
Acidity of Waste vs pH
10,000
1,000
100
10
ACIDITY MG/L $CaCO_3$/L WASTE
1.0
3.0
5.0
7.0
9.0
11.0
pH

Widely divergent values were obtained for these calculations (from 95,000 lb/day as $CaCO_3$ to 774,000 lb/day as $CaCO_3$); however, since the results from methods 2, 3 and 4 agree well and since method 4 was made on the pilot plant itself, the value of 250,000 to 275,000 lb acidity/day as $CaCO_3$ is estimated to be the best representation of the present (1971) Village effluent acidity.

The low values measured in method one may have resulted from non-flow proportioned samples and possible low normality of the standard caustic solution used. The high values from method five probably resulted from the fact that standard pH meters are difficult to calibrate accurately at low pH values and that small calibration errors at these low pH's can cause very large errors in measured acidity values (note slope of curve in Figure 8).

NEUTRALIZATION OPTIONS

The following alkaline agents were considered for use as neutralization agents for the Village waste:

1. Caustic Soda (NaOH)
2. Ammonia (NH_3)
3. Limestone ($CaCO_3$)
4. Limestone + Other Agent (NaOH, CaO, etc.)
5. Code H Alkali
6. High Calcium Quicklime
7. Dolomitic Quicklime

Caustic Soda (NaOH)

Yearly chemical costs alone for NaOH would range from \$0.5 to \$2.0 million per year depending on the waste acidity. Such costs are considered to be outside economic consideration.

Ammonia (NH_3)

Depending upon the waste acidity, the effluent ammonia nitrogen content could range between 160 and 560 mg/l in a 24 MGD waste stream. Although there is presently no specific state standard, one of well below 10 mg/l may be expected soon. In addition, such a high ammonia content in the waste could cause fish or other biological toxicity and would cause a substantial rise in the waste total oxygen demand (TOD) due to nitrification of the ammonia. Ammonia is therefore not considered a viable neutralization alternative.

Limestone ($CaCO_3$)

Although limestone is one of the least expensive neutralizing agents available, it is not capable of raising the waste stream pH high enough (8.0-8.5) in a reasonable length of time to yield the necessary heavy metals precipitation. Limestone is therefore not a viable alternative for neutralization of the Village waste.

Limestone + Other Agent (NaOH, CaO, etc.)

The use of limestone for first stage neutralization coupled with some other neutralization agent would require:

1. Duplicate neutralization facilities and control loops increasing capital cost substantially.

2. Aeration between neutralization steps to remove dissolved CO_2 in the waste water and prevent reprecipitation of $CaCO_3$ during the second stage neutralization.

3. Longer reaction times and therefore larger neutralization facilities.

The increased capital cost and operating problems associated with 1 and 3 above, coupled with possible severe air pollution problems (due to air stripping of organics) associated with 2 above, cause two stage neutralization with limestone as a first stage to be considered outside economic consideration.

Code H Alkali

Code H Alkali is presently not available in sufficient quantity for use in the Village application and is therefore not recommended for use.

High Calcium Quicklime (CaO)

High calcium quicklime is able to provide rapid reaction rates and desired effluent pH levels at "competitive"* costs.

Dolomitic Quicklime (CaO + MgO)

Dolomitic quicklime also provides favorable reaction rates and desired effluent pH values at "competitive"* costs. The use of dolomitic quicklime to neutralize the projected Village waste stream (for 1974+) may offer an added advantage in that if the waste's $SO_4^=$ concentration increases (as is anticipated), the use of dolomitic lime could reduce the neutralized waste's calcium content thereby reducing the probability and/or extent of $CaSO_4$ precipitation.

*"Competitive" costs are considered to be close relative costs as compared with some other agent such as NaOH. The determination of the best economic alternative (along with other considerations) will be carried out as part of the final process optimization.

METALS REMOVAL WITH LIME

DISCUSSION OF TEST WORK

As can be seen from Table 14 copper, total iron, lead and zinc were in violation of the State Effluent Standards in the raw waste during the pilot plant run. Treatment using lime to precipitate the metal hydroxides was investigated during the pilot plant study. The solubility of metal hydroxides varies with pH with the mimimum solubility usually occurring at high pH. Exceptions to this would be metals which form amphoteric hydroxides which will resolubilize at higher pH's.

As can be seen from the enclosed experimental data, (Tables 23and 24) both zinc and copper exhibit some degree of resolubilizing at higher pH, zinc much more so than copper. This effect is reduced somewhat in the presence of other metals. Also, the mimimum solubility of zinc and copper occurs at a lower pH when both metals are in solution.

The pH of the pilot plant neutralization step was therefore controlled at pH 8.5 to take advantage of the lower hydroxide solubility at higher pH while not raising the pH high enough to resolubilize zinc.

DISCUSSION OF RESULTS

The copper level was observed to average 0.12 mg/l in the chemical system effluent with an upper 1 σ limit of 0.23 indicating that the proposed 1 mg/l standard for copper can be met. The total iron concentration was 1.7 mg/l in the effluent and the proposed standard is 2.0 mg/l. Dissolved was not detected in the effluent. Lead was also not detected. Zinc levels averaged 0.1 mg/l in the effluent with a +1 σ of 0.7 mg/l which is well below the mg/l proposed standard.

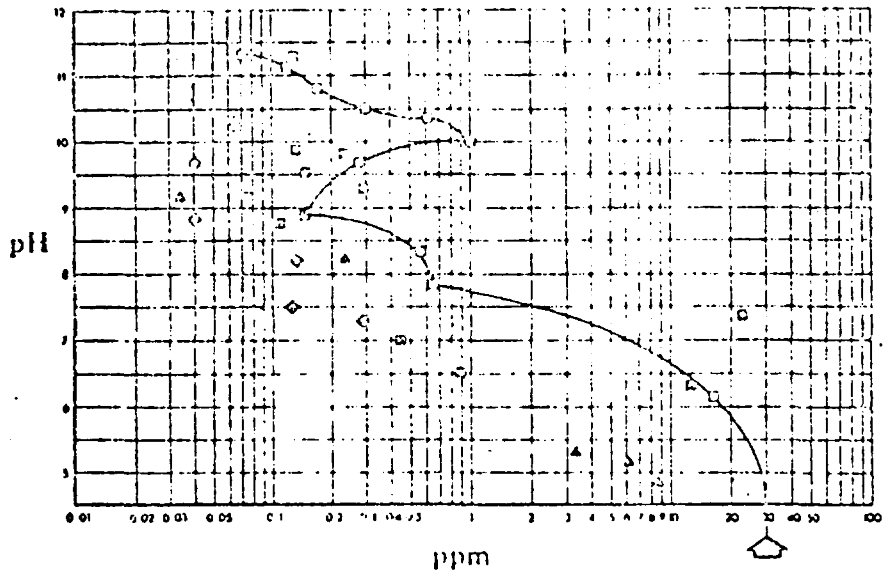
Of the metals not in violation of the standards in the raw waste, substantial reductions were also observed. Cadmium was observed at 0.12 mg/1 in the raw waste which is below the standard of 0.15 mg/1. The +1 σ— concentration was at 0.18 however. Cadmium was reduced to <0.01 mg/1. Manganese and nickel were reduced to levels even further below their respective standards. Arsenic appears to have increased in the effluent; however, this apparent increase is probably due to the removal of slight interferences with the test by the chemical treatment system.

The values in Table 15 have been reported separately because two different methods were used. A colorimetric method was used in the first case and atomic absorption in the second. In both cases the values are below the adopted standards.

COPPER

TABLE 23

METALS REMOVAL WITH LIME



. Residual concentrations of cupric ion in supernatant liquor after lime treatment. Initial concentration of copper was 30 ppm. Registers off graph denote concentrations below limit of detectability.

—□— Copper alone

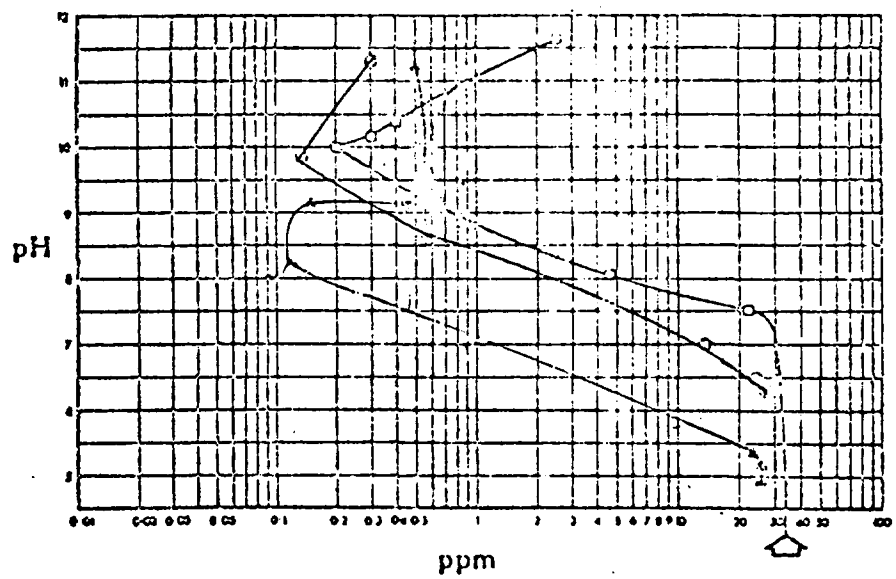
□ With zinc

∠. With zinc and chromium

▽ With zinc and nickel

◇ With nickel

ZINC



Residual concentrations of zinc ion in supernatant liquor after lime treatment. Initial concentration of zinc was 33 ppm.

—□— Zinc alone

○ With copper

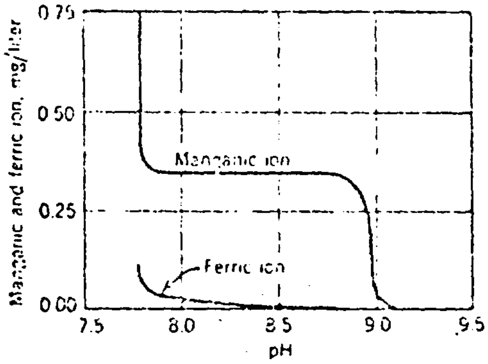
△ With copper and chromium

▽ With copper and nickel

IRON & MANGANESE

TABLE 24

METALS REMOVAL WITH LIME



. Removal of manganic and ferric ion in treated water at various pH values. Based on data presented in R. S. Weston, "Manganese in Water, Its Occurrence and Removal," *J. AWWA*, 24 (1932), 1272.

TABLE 15

SUMMARY TABLE

METALS REMOVAL WITH LIME

Metal	Raw Waste Avg/Mean mg/l	$+\sigma$	$-\sigma$	No. Obs.	Chemical System Effluent Avg/Mean mg/l	$+\sigma$	$-\sigma$	No. Obs.	Avg. % Rem.
As	ND			3	$<0.2/0.087$			3/2	-
Ba	ND			3	ND				-
Cd	0.12	0.18	0.04	13	<0.01	0.043	<0.01	46	92
Cr	ND			3	ND				-
Co	1.2	2.0	0.4	14	0.12	0.23	0.05	60	90
Fe (total)	15.7			3	1.7			5	89
Fe (dissolved)	16.6			11	ND			8	-
Pb	2.1			3	ND			5	-
Mn	0.7			3	0.41			5	41
Ni	0.3			3	0.24			5	20
Se	ND			3	ND				-
Ag	ND			3	ND				-
Zn	9.6			7	0.1	0.7	<0.01	37	99

TABLE 26

PILOT PLANT

HEAVY METALS

METHOD: ATOMIC ABSORBTION

	Raw Influent		CHEMICAL SYSTEM EFFLUENT Acidified-Filtered		CHEMICAL SYSTEM EFFLUENT Filtered-Acidified	
Date	Cu (ppm)	Cd (ppm)	Cu (ppm)	Cd (ppm)	Cu (ppm)	Cd (ppm)
7-13-71			0.190	0.038	0.110	0.053
14	1.5	0.180	0.075	<0.01	0.060	0.010
15			0.120	<0.01	0.110	<0.01
16	1.0	0.082	0.140	0.053	0.112	0.038
17	0.8	0.090	0.320	0.070	0.150	0.070
18			0.230	0.028	0.322	0.024
19			0.205	<0.01	0.210	0.038
20	1.75	0.038	0.390	0.010	0.250	0.014
21			0.322	<0.01	0.135	<0.01
23			0.095	<0.01	0.063	<0.01
24			0.063	<0.01	0.095	<0.01
25			0.063	<0.01	0.060	<0.01
26			0.131	<0.01	0.110	<0.01
Avg.	1.26	0.098	0.180	0.021	2.137	0.024
	0.38	[illegible]				

Note: Detection Limits

Copper - 0.01
Cadmium - 0.5

TABLE 26

PILOT PLANT

HEAVY METALS

METHOD: SOLVENT EXTRACTION

Date	Raw Influent Zn (ppm)	Raw Influent Cu (ppm)	Raw Influent Cd (ppm)	Chemical System Effluent Zn (ppm)	Chemical System Effluent Cu (ppm)	Chemical System Effluent Cd (ppm)
7-13-71				1.0		
14				0.65		
15				<0.05		
16				0.05		
17				3.2		
18				1.6		
19				0.75		
20				1.3		
21				<0.05		
23				<0.05		
24				<0.05		
25				<0.05		
26				0.9		
27				0.7	0.12	0.036
28	7.0	1.1	0.100	0.25	0.16	0.022
29				0.25	0.13	0.024
30				0.25	0.03	<0.1
31				0.25	0.115	0.010
8- 1-71				0.45	0.065	<0.01
3				1.2	0.24	0.022
4				0.25	0.15	N.D.
5/6				0.25	0.075	N.D.
6	5.3	1.6	0.112			
7				4.4	0.02	N.D.
10				8.0	1.4	0.150
11				6.2	0.205	0.074
12				0.05	0.085	N.D.
13	9.5	2.1	0.136	0.15	0.150	N.D.
15	11.0	0.86	0.560			
Avg.	8.2	1.4	**0.224**	**1.20**	0.21	**0.35**

Note: Detection Limits
Zinc - 0.05
Copper - 0.01
Cadmium - 0.01

TABLE 26

PILOT PLANT

HEAVY METALS

CARBON SAMPLES - FINAL EFFLUENT

METHOD: SOLVENT EXTRACTION

Date	Time	Column	Copper	Cadmium	Zinc
6- 6-71	4:15 PM	II	< 0.01	< 0.01	0.02
6	11:00 AM	III	0.028	< 0.01	0.01
6	12:30 PM	III	< 0.01	< 0.01	0.01
6	2:30 PM	III	< 0.01	< 0.01	0.02
6	4:15 PM	III	< 0.01	< 0.01	< 0.01
6- 9-71	-	IV	< 0.01	< 0.01	-
6-13-71	-	IV	< 0.01	< 0.01	0.25
6-14-71	-	IV	< 0.01	< 0.01	0.02
6-15-71	-	IV	< 0.01	< 0.01	0.06

Note: Detection Limits Zinc - 0.01
Copper - 0.01
Cadmium - 0.01

TABLE 26

PILOT PLANT

HEAVY METALS

METHOD: SOLVENT EXTRACTION

Date	Raw Influent		Chemical System Effluent		Carbon Column Final Effluent	
	Cu (ppm)	Cd (ppm)	Cu (ppm)	Cd (ppm)	Cu (ppm)	Cd (ppm)
6- 4-71					<0.01	<0.01
6					<0.01	<0.01
7					<0.01	<0.01
12(6AM)					·0.10	<0.01
12(4PM)					<0.01	<0.01
13					0.024	0.010
16/17			0.21	0.23		
18			0.18	0.41		
22			-	0.05		
23			0.34	0.10		
24			0.24	<0.01		
25			0.14	0.11		
26			0.11	<0.01		
27			0.12	<0.01		
28			0.10	0.02		
29			0.16	0.04		
30			0.15	<0.01		
7- 1-71			0.13	<0.01		
2			0.06	<0.01		
3	1.0	0.2	0.24	0.03		
4	0.5	0.2	-	0.31		
5	0.5	0.2	0.02	<0.01		
6			0.10	<0.01		
7			0.05	<0.01		
8			0.05	0.010		
9			0.01	<0.01		
10			0.03	<0.01		
11			0.03	<0.01		
12			0.02	<0.01		
Avg.	0.66	0.2	0.119	0.06	**0.03**	**<0.01**

Note: Detection Limits

Copper - 0.01
Cadmium - 0.01

TABLE 26

DARCO CARBON

VIRGIN vs. REGENERATED | SAUGET vs. DAYTON

		VIRGIN						REGENERATED					
		Copper		Zinc		Cadmium		Copper		Zinc		Cadmium	
Date	Time	Sauget	Dayton	Sauget	Dayton	Sauget	Dayton	Sauget	Dayton	Sauget	Dayton	Sauget	Dayton
9/10	12- 1 PM	<0.01	-	0.10	-	0.13	-	<0.01	-	<0.01	-	0.01	-
	4- 5 PM	<0.01	0.029	N.D.	N.D.	0.010	0.019	<0.01	N.D.	N.D	N.D	0.025	N.D.
	7- 8 PM	<0.01	0.039	N.D.	N.D.	0.013	N.D.	<0.01	0.040	N.D.	N.D	0.028	N.D.
	9-10 PM	<0.01	0.032	N.D.	N.D.	0.013	0.010	<0.01	0.040	N.D.	0.094	0.021	N.D.
	11-12 PM	<0.01	0.024	<0.01	N.D.	<0.01	N.D.	<0.01	0.052	<0.01	0.110	0.046	N.D.
9/11	1- 2 AM	<0.01	0.100	N.D.	N.D.	<0.01	0.011	<0.01	0.110	<0.01	0.150	0.025	0.015
	3- 4 AM	<0.01	-	N.D.	-	0.013	-	<0.01	0.089	<0.01	0.160	0.023	N.D.
	5- 6 AM	<0.01	0.073	0.067	N.D.	0.039	N.D.	<0.01	0.110	<0.01	0.200	0.042	N.D.
	7- 8 AM	<0.01	0.060	<0.01	N.D.	0.013	0.012	<0.01	0.053	<0.01	0.059	0.021	N.D.
	9-10 AM	<0.01	0.047	0.015	N.D.	0.013	N.D.	<0.01	0.046	<0.01	0.160	0.029	N.D.
	11-12 AM	<0.01	0.054	<0.01	0.059	0.013	N.D.	<0.01	0.130	<0.01	0.330	0.028	0.014
	1- 2 AM	<0.01	-	<0.01	-	<0.01	-	<0.01	0.066	0.076	0.170	0.028	0.036
Average		<0.01	0.050	0.023	N.D.	0.022	0.006	<0.01	0.067	0.007	0.013	0.021	0.015

Note: Method Used - Dayton - Atomic Absorbtion
Sauget - Solvent Extraction

Detection Limits:	Sauget	Dayton
Copper -	.01	.02
Zinc -	.01	.01
Cadmium -	.01	.01

N.D. Not Detected

APPENDIX III

COAGULATION STUDIES

DISCUSSION OF TEST WORK

High molecular weight polymers find uses in waste treatment as flocculants, flocculant aids, filtration aids and sludge conditioning agents. The specific purpose of this work was to find the polymer which would produce the lowest suspended solids level in the effluent from the clarification operation.

There are three basic types of polyelectrolytes - anionic, cationic and nonionic. The cationic polymers generally find use as filtration aids and sludge conditioning agents. The anionic and nonionic polymers are generally used as flocculants and flocculant aids.

Finding the right polymer for the Sauget application was separated into three steps: (1) initial screening, (2) jar testing and (3) pilot plant testing.

INITIAL SCREENING

The purpose of the initial screening tests was to determine the type of polymer (anionic, cationic or nonionic) best suited for coagulation of the waste. Table 27 summarizes the types, manufacturers and costs of the polymers tested.

The results of the initial screening work are shown in Table 28 . The three classes of polymers were evaluated by adding a known amount of polymer to a sample, agitating, observing floc formation, settling in Imhoff cones, and comparing an untreated blank. As can be seen from the suspended solids levels in the supernatant, the cationic polymers did not perform well. The anionic and nonionic polymers were selected for further test work based on the suspended solids levels remaining in the supernatant after 30 minutes of settling. Further testing of cationic polymers confirmed the preliminary screening data (see Tables 29and 30.) (Of the cationic polymers tested, 105C showed quite promising results and was further evaluated.

JAR TEST WORK

The purpose of the jar test work was to decide which specific polymer would provide the best coagulation and to optimize its concentration. The program was initiated using anionic and nonionic polymers; also included were the cationic 105C and sodium silicate. The following experimental procedure was used: A six-stirrer jar test appara-

TABLE 27

POLYELECTROLYTES EVALUATED AS FLOCCULANT AIDS

Company	Anionic	Cost*	Cationic	Cost*	Nonionic	Cost*
Dow	Purifloc A-23	$1.60	Purifloc C-31	$0.40		
Atlas	5A5	$1.60	105C	$1.95	IN	$1.60
	4A4	1.60				
	3A3	1.60				
	2A2	1.60				
	1A1	1.60				
Nalco			600	$0.368	110A	$0.446
			603	0.285		
			605	0.387		
			607	0.364		
American Cyanamid	Magnifloc 835A	$1.35	Magnifloc 521C	$0.275	900N	$1.10
	Magnifloc 836A	1.35	Magnifloc 570C	0.35	905N	1.35
	Magnifloc 837A	1.35	Magnifloc 571C	**		
					Sodium Silicate	0.084

* Cost per pound in 5,000 pound lots, F.O.B. manufacturer.

**No longer produced

TABLE 28

INITIAL POLYELECTROLYTE SCREENING

Reagent	Flask	Polymer Added (ml)	Polymer Added Conc.	Sus. Solids(1) T=0	Sus. Solids(1) T=30	Settling (2) 1	2	5	10	20	30
Control	I	0	0	294	36	0	0	2	5	10	10
Anionic											
Cyanamid 820A	II	2	1 mg/l	294	0	25	30	25	20	20	15
Cyanamid 835A	III	2	1 mg/l	294	0	20	25	20	15	10	15
Dow A-23	IV	1	1 mg/l	294	0	20	20	20	20	15	15
Calgon 269	V	0.5	1 mg/l	294	0	20	15	15	15	15	15
Cationic											
Nalco 607	VI	2	1 mg/l	294	30	0	2	10	10	10	10
Cyanamid 521C	VII	2	1 mg/l	294	24	0	2	10	10	8	10
Cyanamid 560C	VIII	2	1 mg/l	294	0	20	20	20	25	20	15
Nalco 605	IX	1	1 mg/l	294	18	0	2	10	10	10	10
Nalco 600	XIV	1	1 mg/l	294	4	1	10	20	15	12	12
Nalco 603	XV	1	1 mg/l	294	12	1	10	18	15	13	11
Nonionic											
Cyanamid 900N	X	2	1 mg/l	294	0	20	20	20	20	20	15
Cyanamid 905N	XI	2	1 mg/l	294	0	20	20	20	20	15	15
Nalco 110A	XII	1	1 mg/l	294	0	25	30	25	25	20	20
Dow N-17	XIII	2	1 mg/l	294	0	20	25	20	15	15	12

(1) In mg/l.

(2) Milliliters of solids in Inhoff cone after indicated settling periods (in minutes).

tus with a variable speed drive was used for a rapid mix then slow mix for floc formation. Six one liter beakers were filled with raw waste. All samples were neutralized to pH 8.0 with lime (except as noted in the jar test tables). Each beaker was dosed with the appropriate amount of flocculant using a pipette. The beakers were then mixed for one minute at 100 rpm. Observations were made while mixing as to the size and rate of floc formation. After one minute the speed was reduced to 30 rpm and observations were made after one, three, five and ten minutes of flocculation for the size of the floc, the concentration of the particles, the initial rate of settling and supernatant clarity.

The additional testing of the cationic 105C polymer showed that the tested doses of 20 mg/l and 40 mg/l were too high for economic application. In Table 32 the 105C is compared to a blank at low doses. At doses below 1.0 mg/l 105C does not perform satisfactorily; a moderate to light floc remains in suspension.

The next group of flocculants to undergo jar tests were the nonionics. Sodium silicate (silica) was also evaluated with this group. Silica performed adequately (see Table 31) at higher doses (3.5 mg/l) but not well enough below 1.0 mg/l. Nalco 110A (Table 33) performed well at low levels with a concentrated, fine floc developing.

Atlas 1N (Table 34) was tested and found to be unacceptable. At a dose of 2 mg/la light, fine floc remained in suspension.

All the listed anionic polymers underwent jar tests. (See Tables 35 through 44 .) The Dow A-23 did not perform well. The Cyanamid flocculants 836A and 835A performed well, but 837A did not. Of the Atlas polymers tested, the Atlas 2A2 showed the best overall performance. Compared to all the other polymers tested, Atlas 2A2 produced the best effluent quality.

PILOT PLANT TESTING

The effluent suspended solid level observed was greater than the 25 mg/l standard.

The purpose of the pilot plant testing was to verify the jar test results, determine the optimum dose, and define the proper chemical addition point.

Two polymers underwent pilot plant testing over varying periods. Nalco 110A was used during the Pilot Plant run from May 29 through June 2. During this operational period it was evident from general pilot plant operation and effluent appearance that Nalco 110A could not give adequate performance (i.e., effluent suspended solids less than 25 mg/l) in spite of apparently good suspended solids data during the period (30 mg/l ave.).

Atlas 2A2 was added to the feed line of the flocculator clarifier on July 22, 1971. On August 5, 1971, sludge was recycled. Both operations continued until the end of the study. From 7/22/71 through 8/4/71 the suspended solids averaged 37 mg/l. From 8/5/71 through the end of the study on 8/29/71 the mean suspended solids level was 42 mg/l. The clarifier was operating at an overflow rate of 470 gal/day/ ft^2 throughout.

TABLE 29

JAR TEST

Floc Aid: As Listed   Mix Time 1 min.   Mix Speed 100 RPM
Dosage 20 mg/l   Floc Time 9 min.   Floc Speed 30 RPM

Jar	pH	Dosage mg/l	While Stirring	Observations While Flocculating				Remarks
				1 Min.	3 Min.	5 Min.	10 Min.	
1		Blk	B	-	-	C-Z	D	
2		105C	A	-	-	A-X	A-X	
3		521C	B	-	-	C-Z	C-Z	
4		570C	B	-	-	C-Z	B-Y	
5		571C	B	-	-	B-Y	B-Y	
6		C-31	B	-	-	C-Z	D	

CODE: For Floc in Supernatant

SIZE OF FLOC		CONCENTRATION		SETTLING RATE	
1	Large	A	Heavy	X	Fast
2	Medium	B	Moderate	Y	Moderate
3	Fine	C	Light	Z	Slow
4	Very Fine	D	Clear		

TABLE 30

JAR TEST

Floc Aid: As Listed Mix Time 1 min. Mix Speed 100 RPM
Dosage 40 mg/l
Floc Time 9 min. Floc Speed 30 RPM

Jar	pH	Dosage mg/l	While Stirring	Observations While Flocculating 1 Min.	3 Min.	5 Min.	10 Min.	Remarks
1		Blk	B	775		575	475	
2		105C	A	600		400	350	
3		521C	B	800		550	450	
4		570C	B	800		550	450	
5		571C	B	800		550	450	
6		C-31	B	800		550	450	

CODE: For Floc in Supernatant

SIZE OF FLOC	CONCENTRATION	SETTLING RATE
1 Large	A Heavy	X Fast
2 Medium	B Moderate	Y Moderate
3 Fine	C Light	Z Slow
4 Very Fine	D Clear	

*ml of settled material in a graduated 1 liter beaker

TABLE 31

JAR TEST

Floc Aid: Silica   Mix Time 2 min.   Mix Speed 100 RPM

Floc Time 13 min.   Floc Speed 20 RPM

Jar	pH	Dosage mg/l	While Stirring	Observations While Flocculating				Remarks
				1 Min.	3 Min.	5 Min.	10 Min.	
1	8.2	0	3	1-A	-	A	A	
2	8.2	0.5	1-2	1-A	-	B	C-D	
3	8.3	1.0	1	C		C	C-D	
4	8.3	1.5	1	C		C	C-D	
5	8.4	2.5	1	C		C	C-D	
6	8.3	3.5	1-A	C		C-D	D	

CODE: For Floc in Supernatant

SIZE OF FLOC	CONCENTRATION	SETTLING RATE
1 Large	A Heavy	X Fast
2 Medium	B Moderate	Y Moderate
3 Fine	C Light	Z Slow
4 Very Fine	D Clear	

TABLE 32

JAR TEST

Floc Aid: Atlas 105C Mix Time 1 min. Mix Speed 100 RPM

Floc Time 9 min. Floc Speed 30 RPM

Jar	pH	Dosage mg/l	While Stirring	Observations While Flocculating 1 Min.	3 Min.	5 Min.	10 Min.	Remarks
1	2.3	0.00	4	C	C	C		
2	7.0	0.50	3	C	C	C		
3	6.8	0.75	2	C-B	C-B	C		
4	6.8	1.00	2	C	B	B		
5	6.7	1.50	1	C	B	B		
6	7.1	2.00	1	X	B	B		

CODE: For Floc in Supernatant

SIZE OF FLOC	CONCENTRATION	SETTLING RATE
1 Large	A Heavy	X Fast
2 Medium	B Moderate	Y Moderate
3 Fine	C Light	Z Slow
4 Very Fine	D Clear	

TABLE 33

JAR TEST

Floc Aid: Nalco 110A Mix Time 1 min. Mix Speed 100 RPM

Floc Time 9 min. Floc Speed 30 RPM

Jar	pH	Dosage mg/l	While Stirring	Observations While Flocculating				Remarks
				1 Min.	3 Min.	5 Min.	10 Min.	
1	8.3	0.00	3	3	A-3	A-3		
2	8.4	0.50	3	3	A-3	A-3		
3	8.3	0.75	2	2	B	B-2		
4	8.3	1.00	2	2	B	B-2		
5	8.3	1.50	2	2-X	B	B-2		
6	8.3	2.00	2	2-X	B	B-2		

CODE: For Floc in Supernatant

SIZE OF FLOC	CONCENTRATION	SETTLING RATE
1 Large	A Heavy	X Fast
2 Medium	B Moderate	Y Moderate
3 Fine	C Light	Z Slow
4 Very Fine	D Clear	

TABLE 34

JAR TEST

Floc Aid: Atlas IN Mix Time 1 min. Mix Speed 100 RPM

Floc Time 9 min. Floc Speed 30 RPM

Jar	pH	Dosage mg/l	While Stirring	Observations While Flocculating 1 Min.	3 Min.	5 Min.	10 Min.	Remarks
1	8.0	0.00	3	3-Z	Y	Y	-	
2	8.0	0.50	2	2-Y	B-Y	C-3	-	
3	8.1	0.75	2	2-X	B-Y	C-3	-	
4	8.1	1.00	2	2-X	B-Y	C-3	-	
5	8.1	1.50	2	2-X	3-B	C-3	-	
6	8.1	2.00	2	2-X	3-B	C-3	-	

CODE: For Floc in Supernatant

SIZE OF FLOC	CONCENTRATION	SETTLING RATE
1 Large	A Heavy	X Fast
2 Medium	B Moderate	Y Moderate
3 Fine	C Light	Z Slow
4 Very Fine	D Clear	

TABLE 35

JAR TEST

Floc Aid: Purifloc A-23 Mix Time 1 min. Mix Speed 100 RPM

Floc Time 9 min. Floc Speed 30 RPM

Jar	pH	Dosage mg/l	While Stirring	Observations While Flocculating				Remarks
				1 Min.	3 Min.	5 Min.	10 Min.	
1	8.8	0.50	D	B	B	B		
2	9.2	1.00	C	B	B	B		
3	9.5	1.50	B	B-X	B	B		
4	10.0	2.00	B	X	B	C-B		
5	9.5	2.50	B	X	B	C-B		
6	10.5	3.00	A	X	C	C		

CODE: For Floc in Supernatant

SIZE OF FLOC	CONCENTRATION	SETTLING RATE
1 Large	A Heavy	X Fast
2 Medium	B Moderate	Y Moderate
3 Fine	C Light	Z Slow
4 Very Fine	D Clear	

TABLE 36

JAR TEST

Floc Aid: 835A   Mix Time 1 min.   Mix Speed 100 RPM

Floc Time 9 min.   Floc Speed 30-40 RPM

Jar	pH	Dosage mg/l	While Stirring	Observations While Flocculating 1 Min.	3 Min.	5 Min.	10 Min.	Remarks
1	8.5	0.50	C	C-D	D-C	D-C		
2	8.1	1.00	C-B	C	C	C		
3	7.9	1.50	B	X	X	X		
4	7.8	2.00	B	X	X	X		
5		2.50	B	X	X	X		
6		3.00	B	X	X	X		

CODE: For Floc in Supernatant

SIZE OF FLOC	CONCENTRATION	SETTLING RATE
1 Large	A Heavy	X Fast
2 Medium	B Moderate	Y Moderate
3 Fine	C Light	Z Slow
4 Very Fine	D Clear	

TABLE 37

JAR TEST

Floc Aid: 836A Mix Time 1 min. Mix Speed 100 RPM

Floc Time 9 min. Floc Speed 30-40 RPM

Jar	pH	Dosage mg/l	While Stirring	Observations While Flocculating				Remarks
				1 Min.	3 Min.	5 Min.	10 Min.	
1	8.8	0.5	C	C	C	D		
2	8.4	1.0	C-D	C	C	D		
3	9.6	1.5	B	C-B	C-B	D		
4	8.3	2.0	B	B	B	D		
5	7.9	2.5	B	B	B	D		
6	9.1	3.0	B	B	B-X	D		

CODE: For Floc in Supernatant

SIZE OF FLOC	CONCENTRATION	SETTLING RATE
1 Large	A Heavy	X Fast
2 Medium	B Moderate	Y Moderate
3 Fine	C Light	Z Slow
4 Very Fine	D Clear	

TABLE 38

JAR TEST

Floc Aid: Cyanamid 837A   Mix Time 1 min.   Mix Speed 100 RPM

Floc Time 9 min.   Floc Speed 30 RPM

Jar	pH	Dosage mg/l	While Stirring	Observations While Flocculating				Remarks
				1 Min.	3 Min.	5 Min.	10 Min.	
1	8.3	0.00	3	Z	B	B		
2	8.2	0.50	2	X	3-B	3-B		
3	8.3	0.75	2	X	3-B	3-B		
4	8.3	1.00	1	X	3-B	3-C		
5	8.2	1.50	1	X	3-B	3-C		
6	8.3	2.00	1	X	3-C	C		

CODE: For Floc in Supernatant

SIZE OF FLOC	CONCENTRATION	SETTLING RATE
1 Large	A Heavy	X Fast
2 Medium	B Moderate	Y Moderate
3 Fine	C Light	Z Slow
4 Very Fine	D Clear	

TABLE 39

JAR TEST

Floc Aid: Atlas 1A1 Mix Time ______ min. Mix Speed ______ RPM

Floc Time ______ min. Floc Speed ______ RPM

Jar	pH	Dosage mg/l	While Stirring	Observations While Flocculating				Remarks
				1 Min.	3 Min.	5 Min.	10 Min.	
1	6.8	0	D	C	C	C		
2	7.0	0.50	C	C	C-B	C-B		
3	7.9	0.75	B	B	B	B		
4	7.4	1.00	B	B	B	C-B		
5	7.0	1.50	B-A	B	B	C		
6	8.4	2.00	A	X	3-X	3-C		

CODE: For Floc in Supernatant

SIZE OF FLOC	CONCENTRATION	SETTLING RATE
1 Large	A Heavy	X Fast
2 Medium	B Moderate	Y Moderate
3 Fine	C Light	Z Slow
4 Very Fine	D Clear	

TABLE 40

JAR TEST

Floc Aid: Atlas 2A2 Mix Time 1 min. Mix Speed 100 RPM

Floc Time 9 min. Floc Speed 25 RPM

Jar	pH	Dosage mg/l	While Stirring	Observations While Flocculating 1 Min.	3 Min.	5 Min.	10 Min.	Remarks
1		0	1-A	C-X	4-C	D		X
2		0.50	1-A	C-X	4-C	4-C		X
3		0.75	1-A	C-X	4-C	4-C		X
4		1.00	1-A	C-X	4-C	4-C		X
5		1.50	1-A	3-C-Z	4-C	4-C		X
6		2.00	1-A-X	D-X	D	D		X

CODE: For Floc in Supernatant

SIZE OF FLOC	CONCENTRATION	SETTLING RATE
1 Large	A Heavy	X Fast
2 Medium	B Moderate	Y Moderate
3 Fine	C Light	Z Slow
4 Very Fine	D Clear	

TABLE 41

JAR TEST

Floc Aid: Atlas 2A2 From Carboy Mix Time 1 min. Mix Speed 100 RPM

Floc Time 9 min. Floc Speed 25 RPM

Jar	pH	Dosage mg/l	While Stirring	Observations While Flocculating				Remarks
				1 Min.	3 Min.	5 Min.	10 Min.	
1	8.1	0.50	3	A-3	A-3	A-3	3	
2	↓	0.75	3	A-3	A-3	A-3	3	
3	↓	1.00	3	A-3	A-3	A-3	3	
4	↓	1.50	1	C	D	D		
5	↓	2.00	1	C	D	D		
6	↓	2.50	1-A	C	D+	D		

CODE: For Floc in Supernatant

SIZE OF FLOC	CONCENTRATION	SETTLING RATE
1 Large	A Heavy	X Fast
2 Medium	B Moderate	Y Moderate
3 Fine	C Light	Z Slow
4 Very Fine	D Clear	

TABLE 42

JAR TEST

Floc Aid: Atlas 3A3 Mix Time ______ min. Mix Speed ______ RPM

Floc Time ______ min. Floc Speed ______ RPM

Jar	pH	Dosage mg/l	While Stirring	Observations While Flocculating 1 Min.	3 Min.	5 Min.	10 Min.	Remarks
1	8.4	0.00	D		C			
2	8.4	0.50	A	X	C-D	D		
3	8.4	0.75	B-A	X	C-D	D		
4	8.4	1.00	A	X	C-D	D		
5	8.4	1.50	A	X	C-D	D		
6	8.4	2.00	A	X	C-D	D		

CODE: For Floc in Supernatant

SIZE OF FLOC	CONCENTRATION	SETTLING RATE
1 Large	A Heavy	X Fast
2 Medium	B Moderate	Y Moderate
3 Fine	C Light	Z Slow
4 Very Fine	D Clear	

TABLE 43

JAR TEST

Floc Aid: Atlas 4A4 Mix Time 1 min. Mix Speed 100 RPM

Floc Time 9 min. Floc Speed 30 RPM

Jar	pH	Dosage mg/l	While Stirring	Observations While Flocculating				Remarks
				1 Min.	3 Min.	5 Min.	10 Min.	
1	9.2	0.00	D	C	C	C		
2	9.0	0.50	C	C-D	C-D	B		
3	8.8	0.75	C-B	B	B	D-C		
4	9.3	1.00	B	B-3	3	C		
5	8.8	1.50	B	B-3	3	C		
6	9.1	2.00	B	B-3	3	D-C		

CODE: For Floc in Supernatant

SIZE OF FLOC		CONCENTRATION		SETTLING RATE	
1	Large	A	Heavy	X	Fast
2	Medium	B	Moderate	Y	Moderate
3	Fine	C	Light	Z	Slow
4	Very Fine	D	Clear		

TABLE 44

JAR TEST

Floc Aid: Atlas 5A5 Anionic   Mix Time ______ min.   Mix Speed ______ RPM

Floc Time ______ min.   Floc Speed ______ RPM

Jar	pH	Dosage mg/l	While Stirring	Observations While Flocculating 1 Min.	3 Min.	5 Min.	10 Min.	Remarks
1	8.2	0.00	C	C	4	4		
2	8.3	0.50	B	B	3	3		
3	8.7	0.75	2	B	3	3		
4		1.00	A	A-X	3	3		
5	8.0	1.50	A	A-X	3	3		
6	8.0	2.00	A	A-X	3	3		

CODE: For Floc in Supernatant

SIZE OF FLOC	CONCENTRATION	SETTLING RATE
1 Large	A Heavy	X Fast
2 Medium	B Moderate	Y Moderate
3 Fine	C Light	Z Slow
4 Very Fine	D Clear	

REC'D ... 13 1972

ICI America Inc.

POLLUTION CONTROL VENTURE DEPT.

Wilmington, Delaware 19899
(302) 658-9311

April 11, 1972

Mr. Bruce C. Davis
Monsanto Enviro-Chem Systems, Inc.
10 South Riverside Plaza
Chicago, Illinois 60606

Dear Mr. Davis:

We were pleased to hear that you are considering recommending ATLASEP 2A2 in a commercial application. As you requested, we are supplying the following information:

Commercial Availability - The complete line of ATLASEP flocculants is commercially available. We maintain adequate inventories of each product so that delivery is prompt.

Price Schedule - In purchases under 500 lbs., ATLASEP 2A2 sells for $1.90/lb.; between 500 and 1,950 lbs., its price is $1.70/lb. Prices are further discounted in several steps to $1.40/lb. for 5 ton orders. All prices are f.o.b. Wilmington, Delaware, and are for all anionic ATLASEPs. We would be pleased to supply further price information on larger orders, if your application calls for them.

Please let me know if we can be of further assistance.

Very truly yours,

RA Fenimore

Robert A. Fenimore
Project Leader

ap

APPENDIX IV

CLARIFIER DESIGN

DISCUSSION OF RESULTS; CLARIFIER DESIGN

There are three major types of settling: particulate, flocculant and zone.* The type of settling which would normally result from the neutralization and chemical treatment of the Sauget waste stream is a hybrid particulate-flocculant sedimentation. Because of this settling condition which caused high solids carry-over from the chemical system clarifier, the underflow sludge from the clarifier was recirculated and mixed with the clarifier influent during a portion of the pilot plant studies. This recirculation was carried out in an attempt to improve effluent quality in the following ways:

1. To provide additional sites for floc formation and entrapment of small, non-settable particles formed during neutralization.

2. Increase the clarifier influent solids concentration sufficiently to yield zone settling characteristics.

It was felt that an added advantage in the full-scale plant might be obtained by recirculating a portion of the underflow sludge into the raw influent and allowing a first stage contacting step. In this pre-neutralization step, part of the residual sludge alkalinity in the form of unreacted lime and the $CaCO_3$ might be reclaimable. The feasibility of this alternative will be evaluated as part of the final process optimization. Recirculation of underflow sludge into a pre-neutralization step was not explored during the pilot plant studies.

From August 11, 1971 through the end of the study, the pilot plant clarifier was operated with sludge recycle in an attempt to determine if improved settling characteristics and effluent quality could be obtained. Sufficient sludge

*Zone settling is known to be part of the compression or thickening stage of flocculant settling. However, since zone settling is encountered quite frequently, it is often considered as a separate type of settling.

was recycled to maintain zone settling conditions. In spite of the sludge recycle and polyelectrolyte addition (to improve coagulation) the neutralized waste stream continued to exhibit "secondary"* settling characteristics. Sufficient suspended (filterable) solids were contained in the settled effluent to prevent it from meeting the State of Illinois effluent criterion (25 mg/l total suspended solids). This secondary settling characteristic can significantly influence final clarifier design as is indicated later in the content.

In order to determine clarifier design, two major design parameters must be defined: through-put and clarifier overflow rate. Plant through-put is equal to the design flow rate. The clarifier overflow rate (assuming sludge recycle) is determined by zone settling curves constructed from data as listed in Table 45. These data were obtained by measuring settling interface height (in a one liter graduate cylinder) versus time. These data were used to construct the settling curves in Figures 11 thru 16. From these curves the clarifier overflow rate may be calculated using two techniques:

1. By determining the maximum downward velocity of the solids interface (V_o in ft/hr).

2. By determining the area solids loading rate (UA) to obtain a specific desired underflow solids concentration.

The calculations are shown graphically in Figures 9 and 10. The results, using the two techniques, are overflow rates of 7500 and 2000 gal/day - ft.^{2} respectively.

* After the zone settling interface has passed, a turbid supernatent remained with quite slow particle settling.

However, these two overflow rates (2000 and 7500 gal/ft^2 - day) appear to be too high from a practical standpoint. During the pilot plant studies, an average clarifier overflow rate of approximately 470 gal/ft^2 - day was maintained; referring to Table 47, it may be seen that even at this low overflow rate, with or without sludge recycle, it was difficult or impossible to maintain acceptable effluent suspended solids concentrations.

During the first period analyzed, the effluent suspended solids concentrations were barely able to satisfy the state effluent criterion. However, the chemical system effluent composite sampler was located in an effluent holding tank where further solids sedimentation was occuring. These non-representative samples caused the apparent low effluent solids content. On or about 6/30/71, the sampler was moved to a location where samples of the free-flowing clarifier effluent were obtained. As may be seen, the effluent average and mean suspended solids concentrations increased measurably. There was no solids recycle during this period (from 7/1 - 8/4/71). However, during the period from 8/5/71 through the end of the study, clarifier underflow sludge was recycled into the neutralization chamber. The average and mean effluent suspended solids concentrations increased measurably during this period, indicating that solids recycle was not helpful in improving the chemical system effluent quality. The recycle appears to have been, in reality, detrimental to effluent quality.

In addition to the periods described above, a "design run" was made between 11/16/71 and 11/17/71 in which the clarifier overflow rate was maintained at 1000 gal/ft^2-day. The effluent solids concentration during this period (excluding upsets) was 56 mg/l which also exceeds the state standard.

From these data it is indicated that the state effluent suspended solids criterion would be difficult or impossible to meet, even at 500 gal/day $ft.^2$ clarifier overflow rate.

One other aspect of the sludge recycle question must be discussed. The proposed effluent for 1974+ is expected to have a substantially increased dissolved solids content.

If sulfate and calcium concentrations are increased sufficiently, the precipitation of $CaSO_4$ (gypsum) may result, causing severe scaling and post-precipitation problems. According to the literature,* sludge recycle is helpful in correcting these problems. The question of sludge recycle desirability from this aspect will be evaluated in the final process design optimization.

* Chemical Treatment of Sewage and Industrial Wastes by Dr. W.A. Parsons (National Lime Association) pp. 65-70.

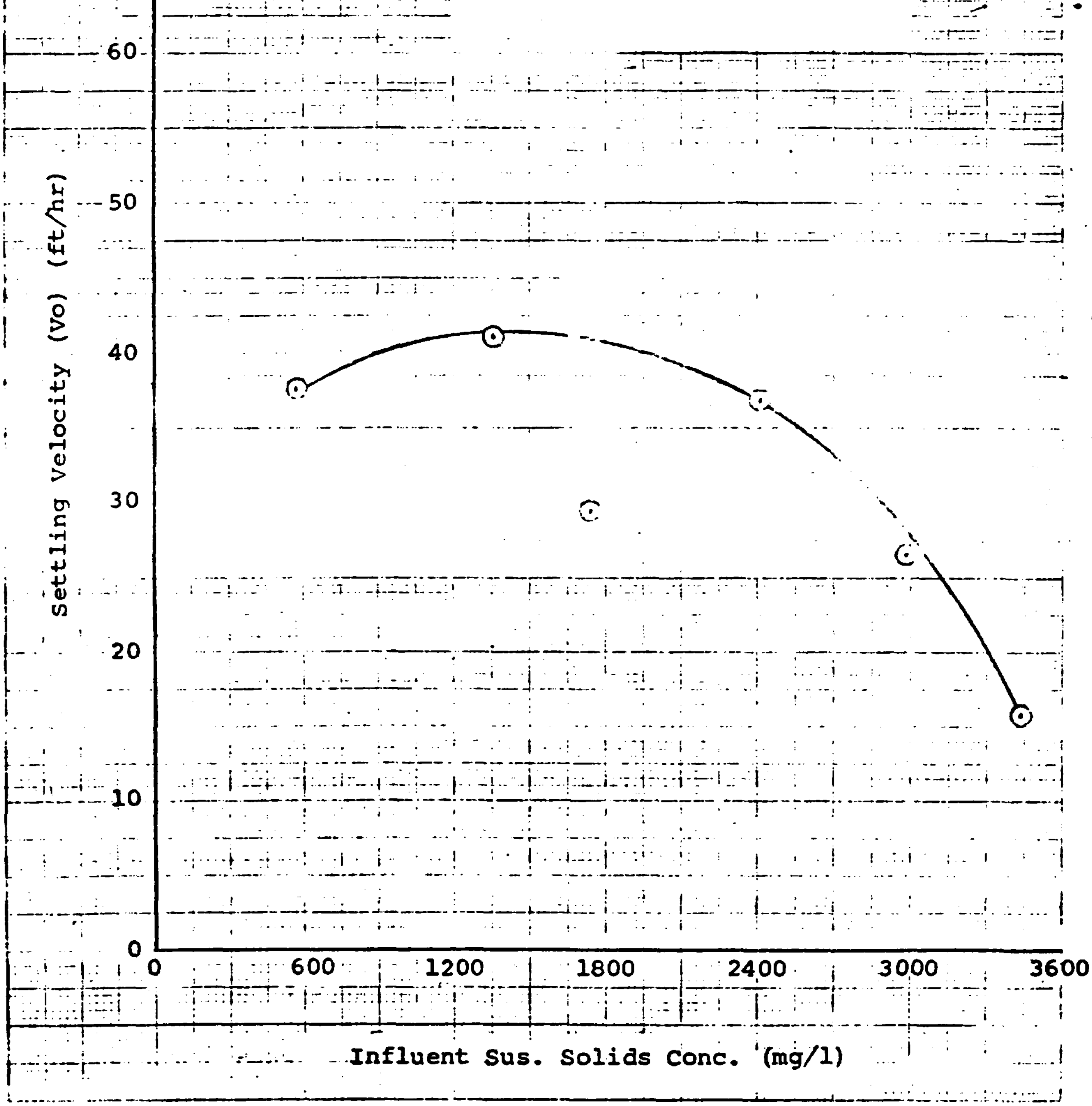
TABLE 45

RAW DATA FOR
ZONE SETTLING* - CONDITION: LIME SLUDGE WITH POLYMER - 9/22/71

t, (min)	Co=570	Co=1360	Co=1740	Co=2420	Co=2930	Co=3410
0	1000	1000	1000	1000	1000	1000
1	980	980	980	980	980	970
2	So thin it	700	800	800	800	850
3	is impossi-	300	400	400	450	650
4	ble to see	150	250	300	400	450
5	settling dur-	70	100	150	250	300
6	ing the first	50	55	80	120	150
7	few minutes	50	50	75	105	130
8	50	50	50	70	100	120
9	50	50	45	65	95	115
10	50	50	40	65	90	110
11	50	50	40	65	85	105
12	50	50	40	60	80	100
13	50	50	40	60	80	95
14	50	50	40	60	80	95
15	50	50	40	60	80	90
16	50	50	40	55	75	90
17	50	50	40	55	70	85
18	50	50	40	50	70	85
19	50	50	37	50	70	85
20	50	50	35	50	68	80
22	50	50	35	48	65	80
24	10	30	35	45	65	75
26	10	30	35	45	60	75
28	10	30	35	45	60	75
30	10	30	35	45	60	70

*All supernatants very turbid with fine particles suspended.

FIGURE 9
Settling Velocity vs
Influent Solids Concentration



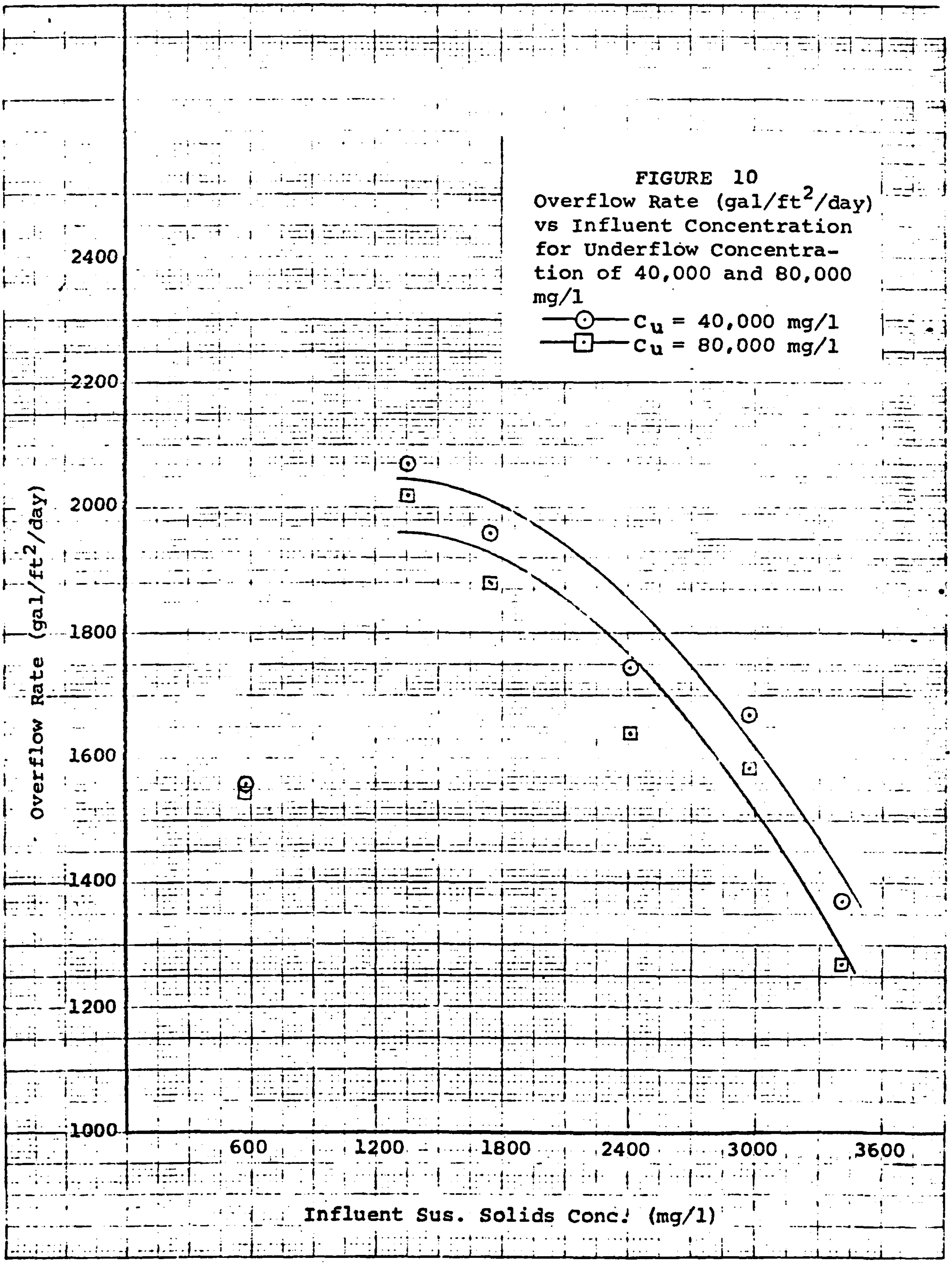


FIGURE 10
Overflow Rate (gal/ft^2/day) vs Influent Concentration for Underflow Concentration of 40,000 and 80,000 mg/l

TABLE 46

BASES FOR CALCULATION OF INITIAL SETTLING VELOCITY (Vo) AND OVERFLOW RATE (OR)

Inf. Conc. (mg/l)	H (ft.)	t (hrs.)	H/t=Vo (ft./hr.)	OR (gal/ft^2/day)
3410	0.783	0.050	15.7	2800
2930	0.895	0.034	26.3	4700
2420	0.783	0.021	37.3	6700
1740	0.895	0.030	29.8	5350
1360	0.895	0.022	40.7	7300
570	0.783	0.021	37.3	6700

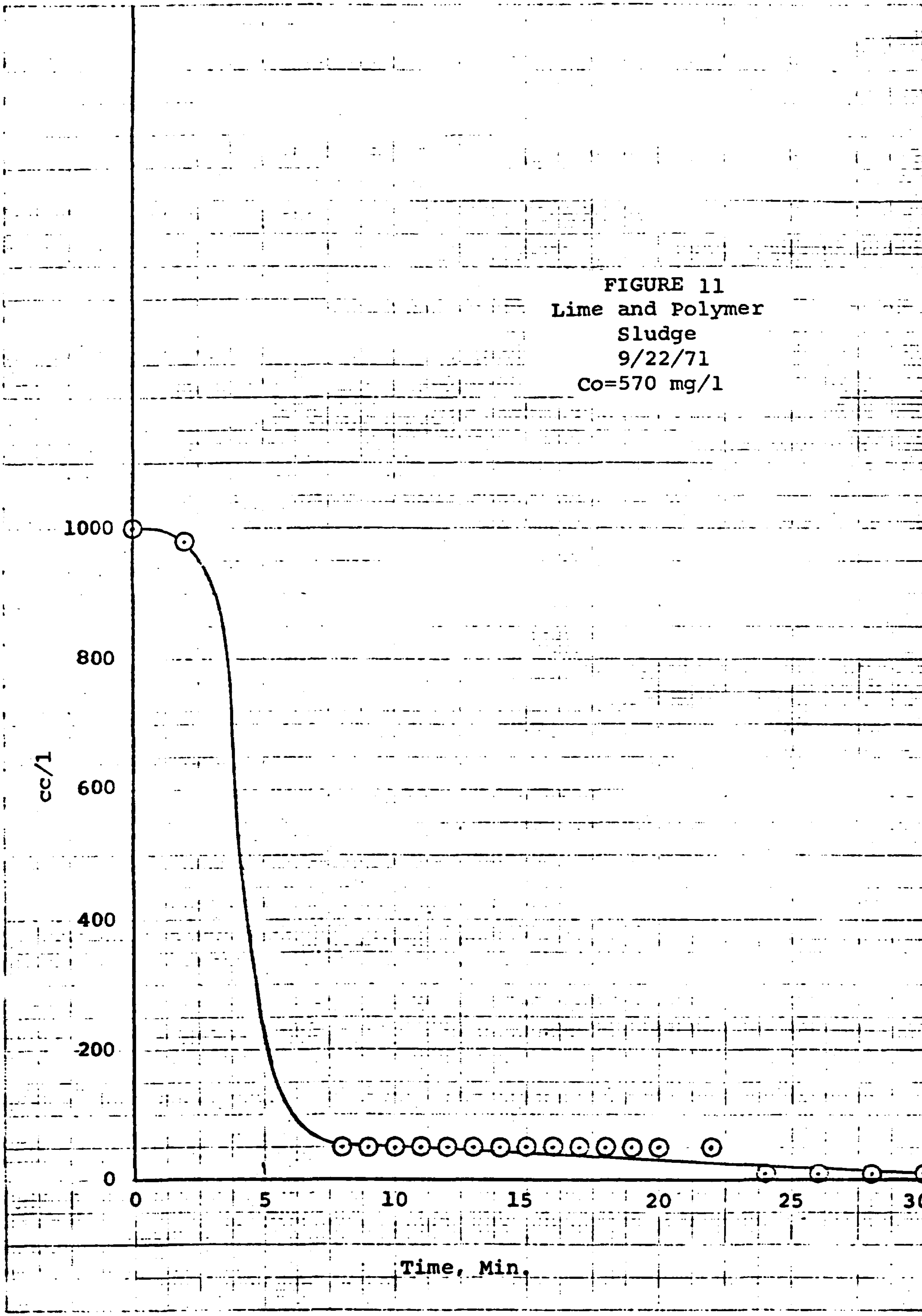


FIGURE 11
Lime and Polymer
Sludge
9/22/71
Co=570 mg/l

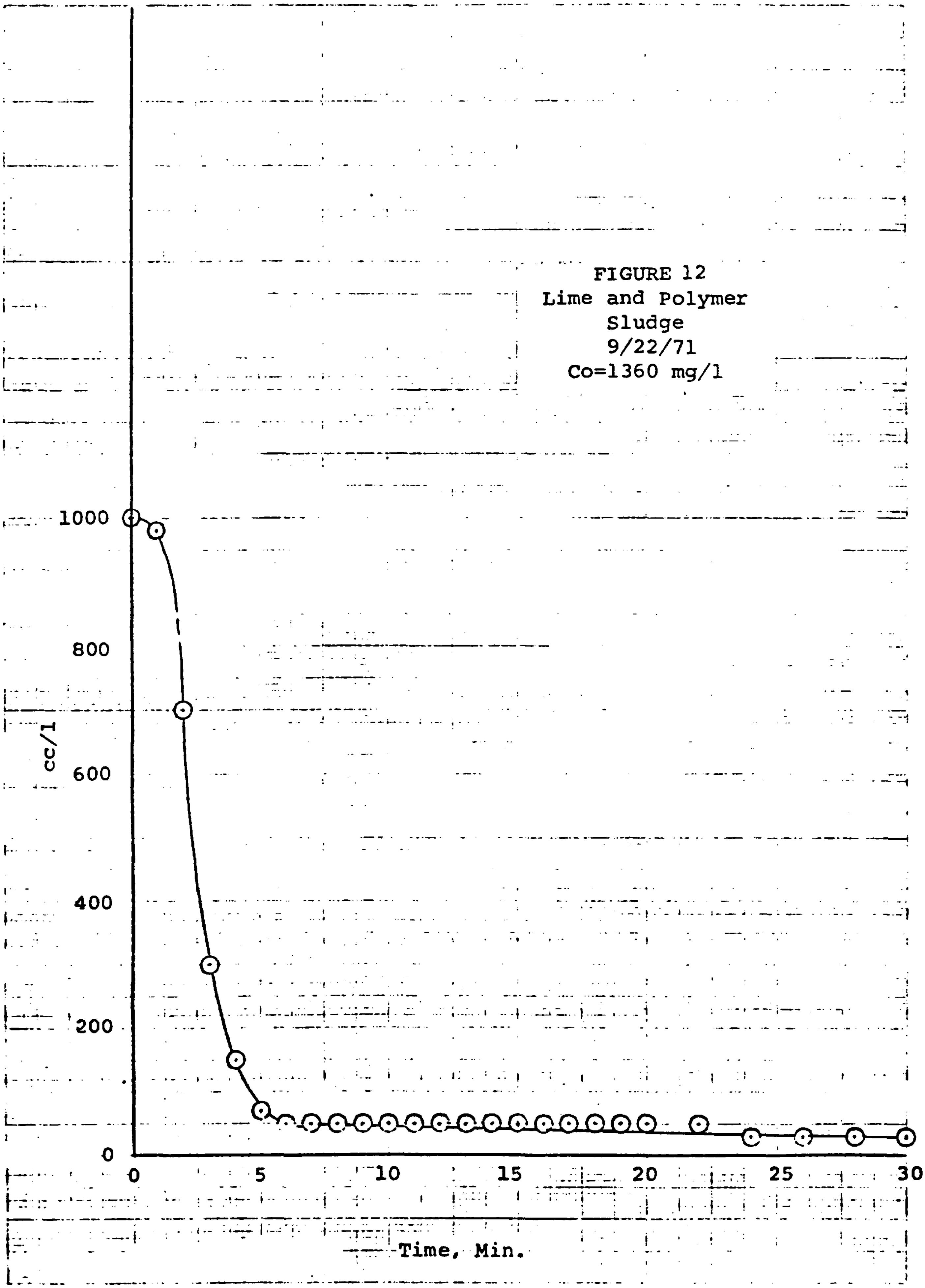


FIGURE 12
Lime and Polymer
Sludge
9/22/71
Co=1360 mg/l
1000
800
600
400
200
0
cc/l
0
5
10
15
20
25
30
Time, Min.

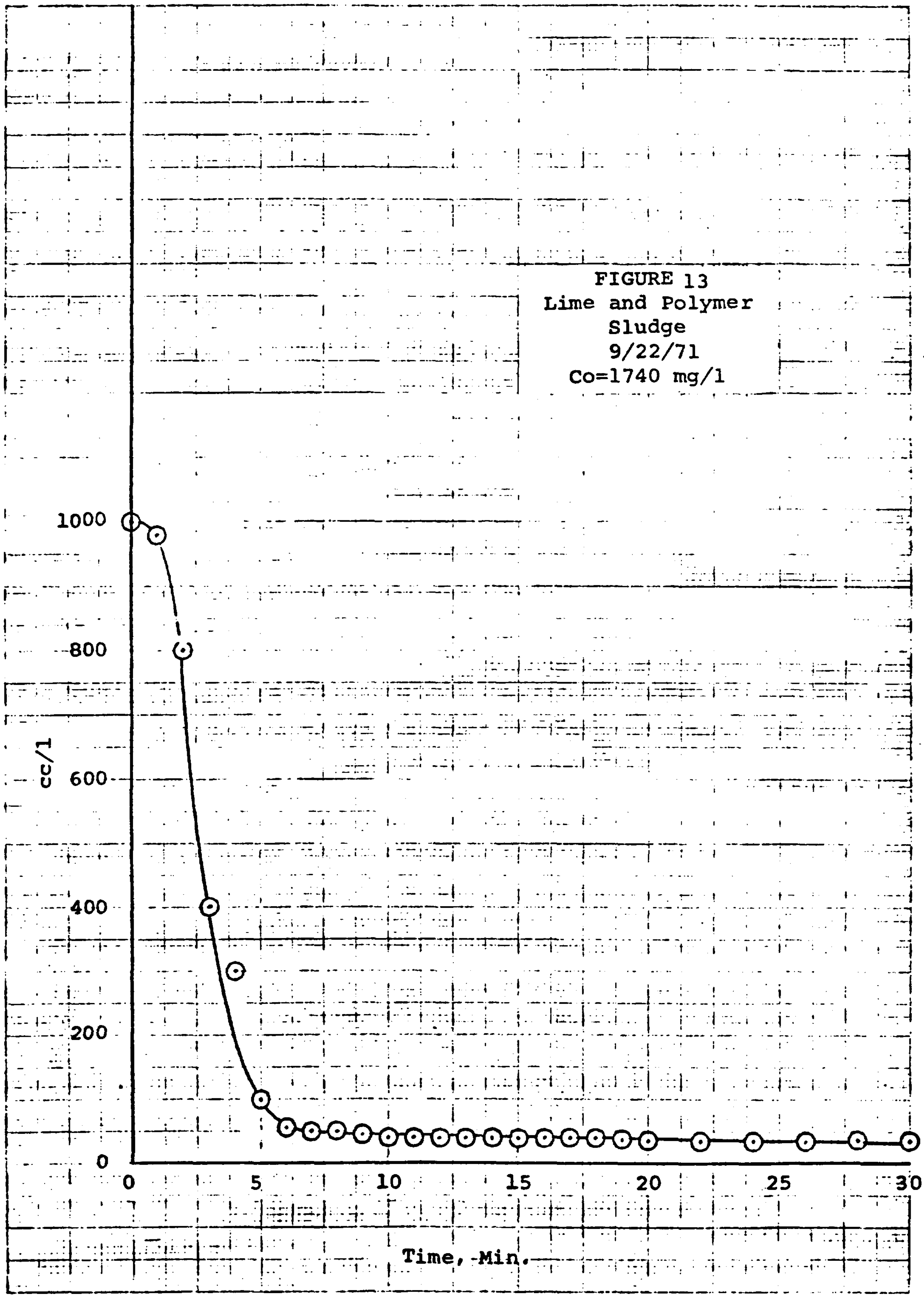


FIGURE 13
Lime and Polymer
Sludge
9/22/71
Co=1740 mg/1
cc/1
1000
800
600
400
200
0
0
5
10
15
20
25
30
Time, Min.

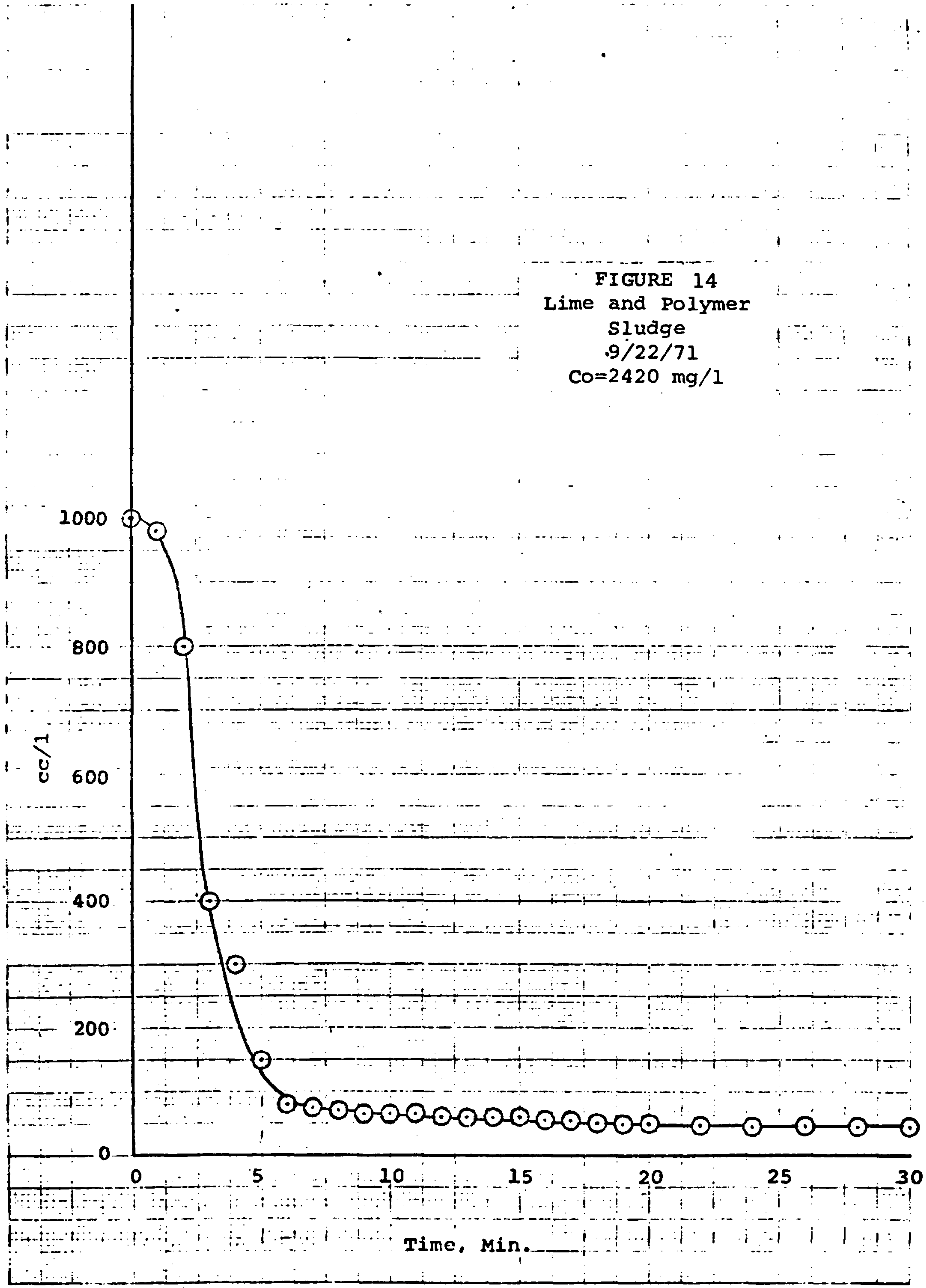


FIGURE 14
Lime and Polymer
Sludge
9/22/71
Co=2420 mg/1

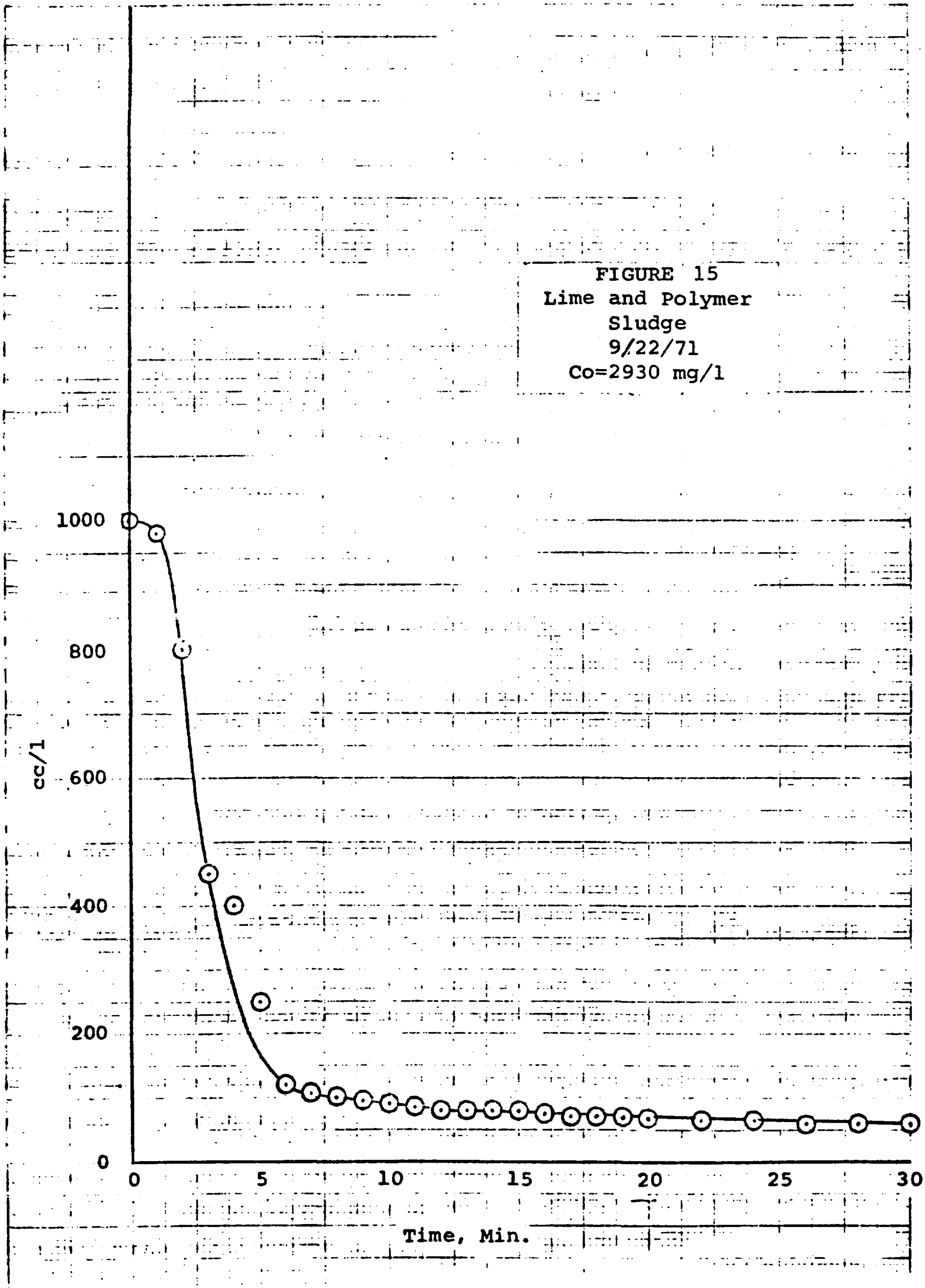


FIGURE 15
Lime and Polymer
Sludge
9/22/71
Co=2930 mg/l
cc/l
1000
800
600
400
200
0
0
5
10
15
20
25
30
Time, Min.

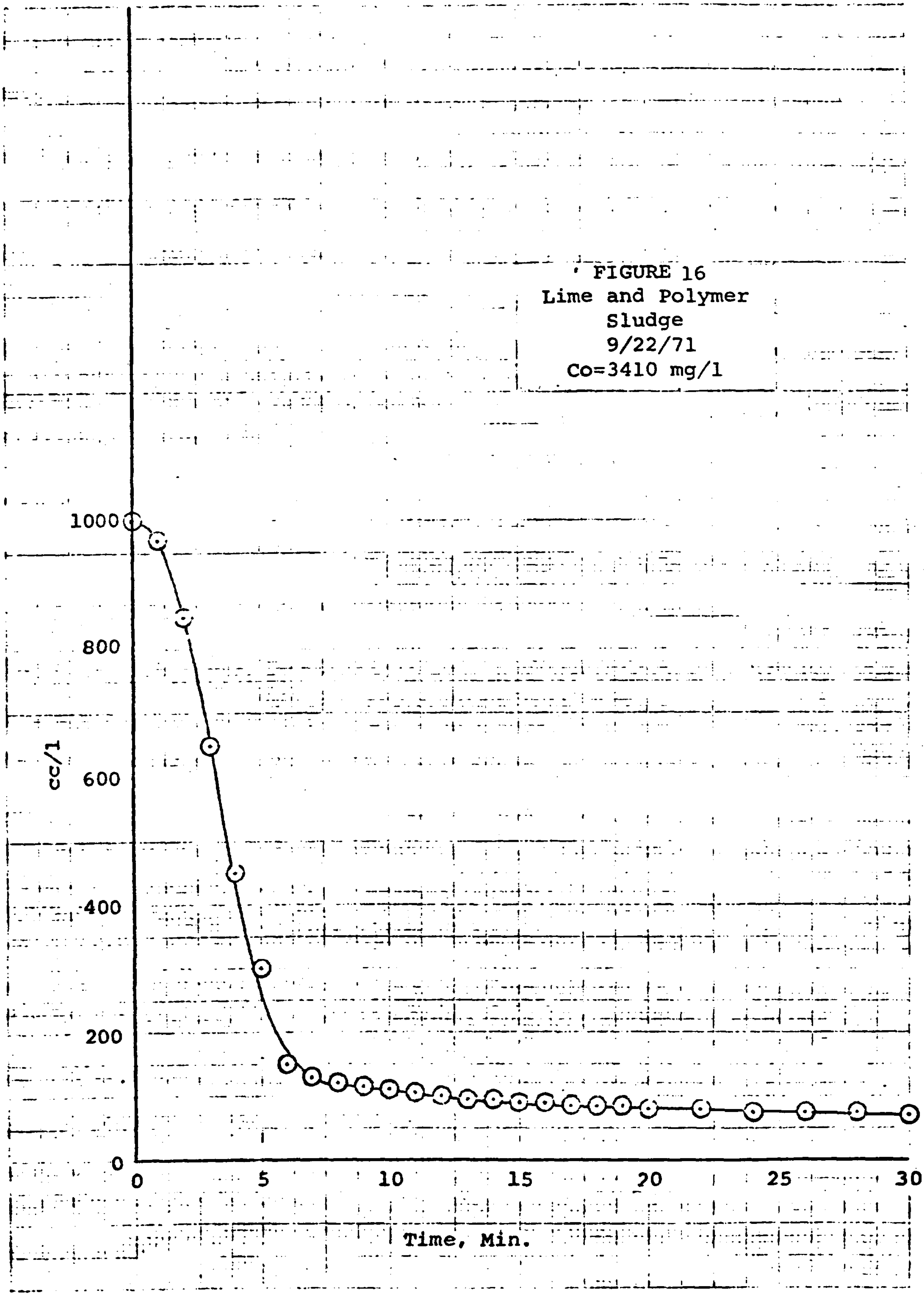


FIGURE 16
Lime and Polymer
Sludge
9/22/71
Co=3410 mg/l
cc/l
1000
800
600
400
200
0
0
5
10
15
20
25
30
Time, Min.

TABLE

PILOT PLANT EFFLUENT SUSPENDED SOLIDS

SUMMARY

Period	Average S.S.	Mean S.S.	No.of Observations
5/22-6/2[illegible]/71	26 mg/l	23 mg/l	27
7/1-8/4/71	40 mg/l	29 mg/l	17
8/5-8/30/71	61 mg/l	42 mg/l	17

APPENDIX V

SLUDGE GENERATION DATA

DISCUSSION OF SLUDGE

GENERATION RATES

Generation Calculations

Final treatment plant design requires a knowledge of the quantity, concentration and character of the sludge generated in the neutralization and sedimentation operations. The sludge collected in this step, plus the sludge collected in the grit chambers of the proposed treatment system, represent the quantity of sludge which will require handling. The grit chamber sludge collection rate is discussed in another section of this report.

The results of the sludge generation calculations are shown in Tables 49 through 52.

Possible Sources of $CaCO_3$ in Sludge

The character and most particularly the high carbonate content of pilot plant sludge is of interest since some residual alkalinity might be reclaimable in commercial plant operation, if a sludge of similar composition is generated.

The analysis of composite lime sludge sample from 5 days of pilot plant operation is shown in Table 53 . As is readily apparent, the major components of this sludge are calcium and carbonate, undoubtedly present as the compound calcium carbonate (limestone). Calculations show that the amount of $CO_3^{=}$ present in the sludge is almost exactly the amount stoichiometrically required to be bound to the calcium in the sludge to form $CaCO_3$. The components shown account for approximately 83% of the sludge dry weight. The character of the unaccounted 17% is unknown, but probably consists partially of sulfate compounds, metal oxides and/or hydroxides and unidentified organic and/or inorganic insolubles. Three possible sources of carbonate (or carbon dioxide) are:

1. Atmosphere

2. CO_2 dissolved in the wastewater.

3. $CO_3^{=}$ in the wastewater during infrequent high pH periods.

These possible $CO_3^{=}$ sources are discussed separately below:

1. Atm)sphere

One possible $CaCO_3$ source may be from absorption and reaction of Ca with atmospheric CO_2 while being slurred in a 200-gallon tank by a 3/4 horsepower propeller-type mixer. Assuming:

a. 50% of the CaO added reacts to $CaCO_3$.
b. Average daily lime dose rate = 7.56 lb/day.
c. Atmosphere is the sole CO_2 or CO_3 = source.
d. 100% CO_2 transfer efficiency (to the water).
e. Dry air is 0.033% CO_2 by volume.
f. Dry air density at 760 mm Hg is 0.001165 gm/ml,

then calculations show that air must be contacted with the lime slurry at a rate of 2500 l/min. (88 cfm) to provid sufficient CO_2 to react with 50% of the average daily lime dose. It should be noted, however, that the location of the Sauget pilot plant was in a highly industrialized metropolitan area with a large power plant very nearby. Also, the exposed sewer outlets and pumping station wet well were in very close proximity to the pilot plant providing an additional source of atmospheric CO_2 enrichment to those described above. It is quite probable, therefore, that the atmosphere in the pilot plant vicinity could be substantially enriched in CO_2, thereby reducing the quantity of air necessary to provide the required CO_2.

2. Dissolved CO_2

Because the Village sewers are located below grade and the fact that large $CO_3^=$ dumps are made into a highly acid waste stream (generating CO_2 gas), it is estimated that the CO_2 partial pressure in the Village sewers could be as high as 0.5 atmosphere or more. Assuming ideal gas behavior over the acid waste streams, it may be calculated by Henry's law that approximately 860 mg/l of CO_2 could be dissolved in the waste water when dumps are occurring. If the waste stream reaching the pilot plant contained half this quantity (on the average) of CO_2, then sufficient CO_2 to react with exactly half the calcium added (in the form of lime) would be provided by the wastewater.

3. Carbonate ($CO_3^=$) in Waste During High pH Periods

Table 54 shows treatment plant influent pH versus time for one 22-hour period of plant operations. During this period, the time and duration of four normal carbonate dumps by Monsanto Krummrich were recorded in an attempt to correlate waste pH peaks with these dumps. Only one dump (9:00 AM) is associated with a waste pH peak. Even this association is tenuous. In addition, the treatment plant influent pH was continuously recorded for an eleven day period from 3/18/72 through 3/27/72. During this period, the waste pH did not exceed 6.0 at any time, and exceeded 5.0 only once. Referring to Figure 17 , it can be seen that the carbonate content of water below pH 7.7 is much less than 1/mg/l; at a pH of 6.0 this ion would be essentially nonexistent. It is therefore felt that the wastewater is a negligible source of carbonate with possible rare exceptions.

TABLE 48

RAW DATA FOR
PILOT PLANT SOLIDS
BALANCE

Day #	Vol. Wasted (gal.)	Conc. (mg/l)	Influent SS* (Raw Waste) (mg/l)	Effluent SS* (mg/l)	Flow (gpm)
7	26.6	26,780	394	52	.92
7	27.5	23,000			-
8	37.8	22,220	44	86	.86
9	16.2	47,280	54	50	.77
11	22.0	35,000	30	82	.62
12	12.9	55,050	20	15	.62
13	10.0	70,480	-	-	.61
19	4.0	144,630	147	11	.55
20	4.0	106,010	60	49	.54
22	35.0	41,750	20	13	.52
24	6.5	-	-	-	.49
25	4.0	-	174	27	.32
26	4.2	41,750	74	17	.49
30	8.0	-	21	10	.55
31	10.0	-	200	28	-
32	6.0	-	-	18	.23
33	6.0	41,450	124	21	.59
34	6.0	-	42	27	.61
36	4.0	54,010	-	-	.75
38	20.0	38,810	62	11	.60
39	8.0	-	109	26	.51
40	8.0	29,550	-	-	.50
43	14.0	-	13	278	-
44	26.0	-	62	58	.49
45	12.0	-	121	36	.76
49	6.0	-	20	12	.50
50	26.0	-	8	13	.46
51	10.0	-	-	-	.52
52	7.0	-	461	103	.76
53	6.0	-	28	11	.76
54	10.0	-	22	42	.58
55	3.0	-	-	14	.66
58	3.5	-	-	-	.54
59	6.0	-	-	-	.51
60	4.0	-	-	-	.45
62	8.0	-	-	-	.49
68	20.0	39,830	-	-	0.5
70	11.0	87,940	-	-	.66
71	7.1	99,240	-	-	.71
74	2.0	99,450	-	22	.60
75	2.1	111,820	-	-	.50
76	8.0	79,710	46	51	.50
78	1.5	152,890	85	30	.50
79	2.0	140,140	119	27	.58
80	2.0	140,600	-	-	.50
82	2.5	291,800	-	-	.50
84	1.0	172,620	30	16	.53
86	3.0	70,780	-	-	.60
93	4.0	115,440	-	113	.58
94	3.0	116,540	40	36	.60
95	6.0	158,740	30	11	.58
96	8.0	71,390	89	9	.58
97	9.0	95,040	85	20	.50
98	6.0	59,800	24	14	.50
99	6.0	-	-	-	.60
104	6.0	-	-	75	.63
105	6.5	95,930	53	48	.55
106	6.0	-	-	-	.50
107	8.0	-	-	-	.55
108	7.0	-	-	26	.60
111	7.0	-	-	-	.65
112	9.0	-	-	-	.60
114	5.5	-	-	-	.55

*Data points are shown for the days listed in column one only. The calculated averages for these parameters are based upon all of the data available for these periods (see Master Data Tables).

TABLE 49
AVERAGE POUNDS SLUDGE PER DAY PER
VOLUME PROCESSED

No. of Days	Vol Slg. Wst'd (gpd)	WST'D SLG. CONC.		FLOW RATE		INF. S. S.		EFF. S. S.	
		mg/l	No. of Obs.	gpd	No. of Obs.	mg/l	No. of Obs.	mg/l	No. of Obs.
Period 1 (Days 7 - 40):									
34	8.43	51,850	15	835	32	77.4	25	36.2	26
Period 2 (Days 68 - 105):									
39	4.08	115,800	19	792	43	63.8	16	54.3	21
Period 3 (Days 7 - 114):									
108	5.83	87,570	34	806	103	75.8	53	46.3	61

TABLE 50
SUMMARY OF SOLIDS GENERATION DATA

Period	lbs. SS in/day/gal. processed	lbs. SS in/day/gal. processed	lbs. SS Wstd. per day	lbs. SS gen./day gal. processed	lbs. SS Requiring Handling*/ 10^6 gal./day
1	0.54	0.25	3.65	0.0040	4400
2	0.42	0.36	3.94	0.0049	5000
3	0.51	0.31	4.26	0.0050	5300

* For the neutralization - sedimentation system only; does not include grit chamber sludge

TABLE 51

SOLIDS GENERATION RATES ASSUMING EFFLUENT
SS CONCENTRATION OF 25 mg/l

Period No.	lb SS allowable/day	lb SS generated / Gal. Processed	lb SS generated / lb Lime Used	lb SS generated / lb Acidity**	lb SS Req. Handling* / Gal. Processed	lb SS Req. Handling* / lb Lime Used	lb SS Req. Handling* / lb Acidity**
1	0.17	0.0039	0.52	0.74	0.0045	0.59	0.85
2	0.17	0.0047	0.44	0.56	0.0052	0.49	0.63
3	0.17	0.0049	0.63	0.75	0.0055	0.70	0.84

*Does not include grit chamber sludge

**As $CaCO_3$

TABLE 52

POUNDS OF SOLIDS GENERATED AND POUNDS OF SOLIDS REQUIRING HANDLING
VERSUS LIME USED AND RAW WASTE ACIDITY

Period No.	lb SS in/day	lb SS out/day	lb SS wasted/day	lb SS generated / lb Lime Used	lb SS* Req. Handling / lb Lime Used	lb SS generated / lb Acidity**	lb SS* Req. Handling / lb Acidity**
1	0.54	0.25	3.64	0.53	0.58	0.75	0.83
2	0.42	0.36	3.94	0.46	0.47	0.59	0.60
3	0.51	0.31	4.26	0.65	0.68	0.78	0.81

*Does not include grit chamber sludge

**As $CaCO_3$

TABLE 53

LIME SLUDGE ANALYSIS

Element	Weight % (dry)
Ca	30
Si	2
Fe	2
Mg	2
Zn	1
Cu	0.4
Na	0.3
Al	0.3
Pb	0.2
Mn	0.1
Sn	0.03
Ni	0.03
Cr	0.02
Ti	0.007
Ag	0.01

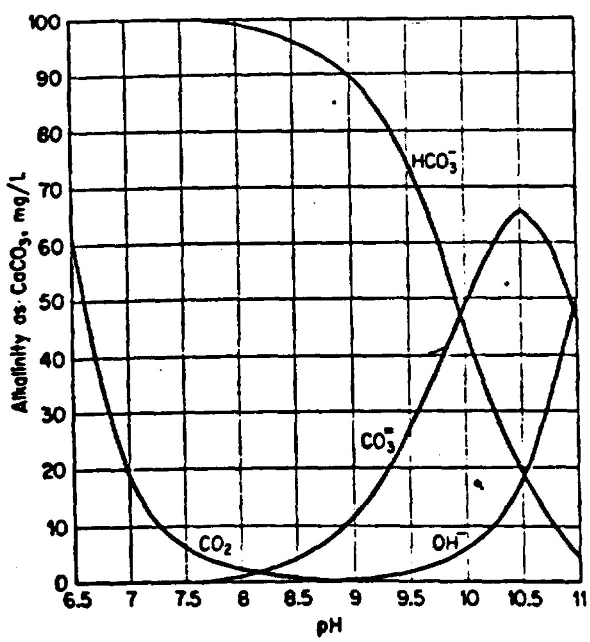
$CO_3^{=} = 44.5\%$

TABLE 54

INFLUENT WASTE pH VERSUS TIME
DURING KRUMMRICH $CO_3^=$ DUMPS

Time	Date	pH	$CO_3^=$ Wash Water Dump
10-11 AM	12/20/71	3.8	9:00 - 9:40 AM
11-12		4.7	
12-1 PM		2.3	
1-2		1.9	
2-3		1.6	3:15 - 4:00 PM
3-4		1.4	
4-5		1.6	
5-6		1.6	
6-7		1.5	
7-8		1.6	
8-9		1.3	9:30 - 10:00 PM
9-10		1.6	
10-11		2.2	
11-12		2.2	
12-1 AM	12/21/71	2.0	
1-2		2.0	
2-3		2.0	
3-4		1.9	3:00 - 3:35 AM
4-5		2.1	
5-6		2.3	
6-7		2.2	
7-8		2.2	

FIGURE 17



APPENDIX VI

SLUDGE DEWATERING

A. Chemical Conditioning

B. Thickening

C. Centrifugation

D. Vacuum Filtration

SLUDGE CONDITIONING

SLUDGE CONDITIONING

Discussion of Test Work

In order to improve dewatering characteristics, wasted sludge often must be "conditioned," prior to vacuum filtration. Conditioning is generally accomplished by the addition of chemical agents (such as $FeCl_3$, lime, polyelectrolytes, etc.) whose purpose is to minimize the specific resistance of the sludge to filtration, thus minimizing the energy required for dewatering.

Specific resistance is a function of the applied vacuum, the filter area, the filtrate viscosity and the initial solids concentration.

Specific resistance is experimentally evaluated at several different conditioner doses and the optimum dose is chosen, i.e., minimum conditioner dose at maximum specific resistance reduction.

The experimental apparatus used for conditioner evaluation is shown in Figure 18 . A sample of pilot plant lime sludge was obtained and the initial suspended solids were measured. Since cationic polyelectrolytes are often used as conditioning aids, the sludge samples were mixed with several different doses of Atlas 105C polyelectrolyte. The results of the specific resistance calculations are shown in Tables 55 and Figure 19.

No minimum specific resistance is apparent for the conditioner doses tested. Although some reduction in resistance is obtained with increasing conditioner dose, to obtain a 50% reduction in the sludge specific resistance requires a polymer dose rate of approximately 14 lbs/ton. Because the 105C polymer costs approximately $2.00 per pound, coupled with the marginal improvement in sludge filterability for such high dose rates, consideration of this type of sludge conditioning is far outside economic consideration using 105C.

Further experimental investigations using actual commercial scale sludge might yield some more feasible conditioning scheme.

FIGURE 18
SPECIFIC RESISTANCE MEASUREMENT
BUCHNER FUNNEL APPARATUS

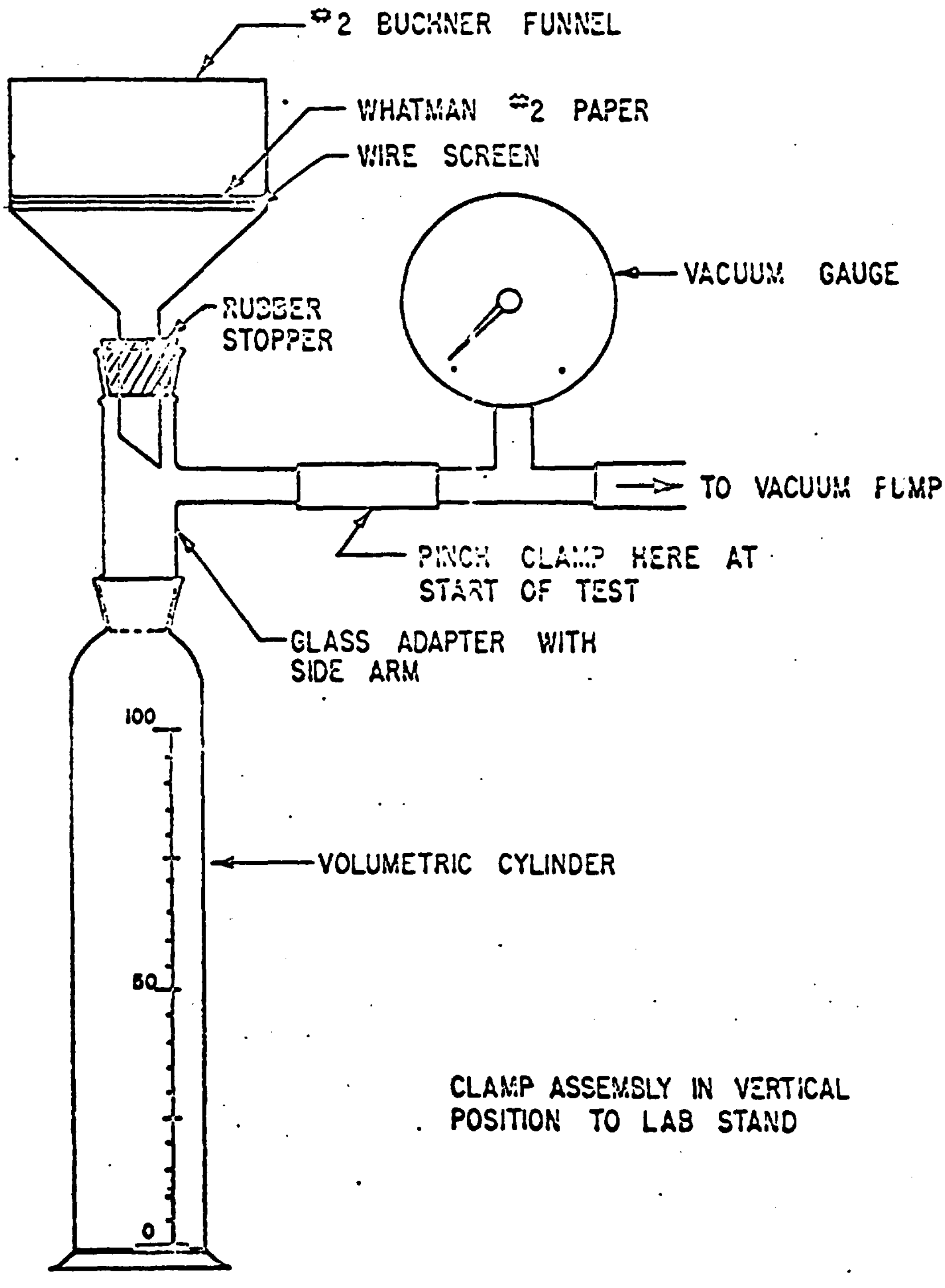


TABLE 55

SLUDGE CONDITIONING RESULTS
USING ATLAS 105C

Coagulant Dose mg/l	Coagulant Dose lbs/ton	Value of Specific Resistance
0	0	1.84×10^5
10	132	1.56×10^5
25	3.31	1.38×10^5
50	6.62	1.47×10^5
100	13.24	1.01×10^5

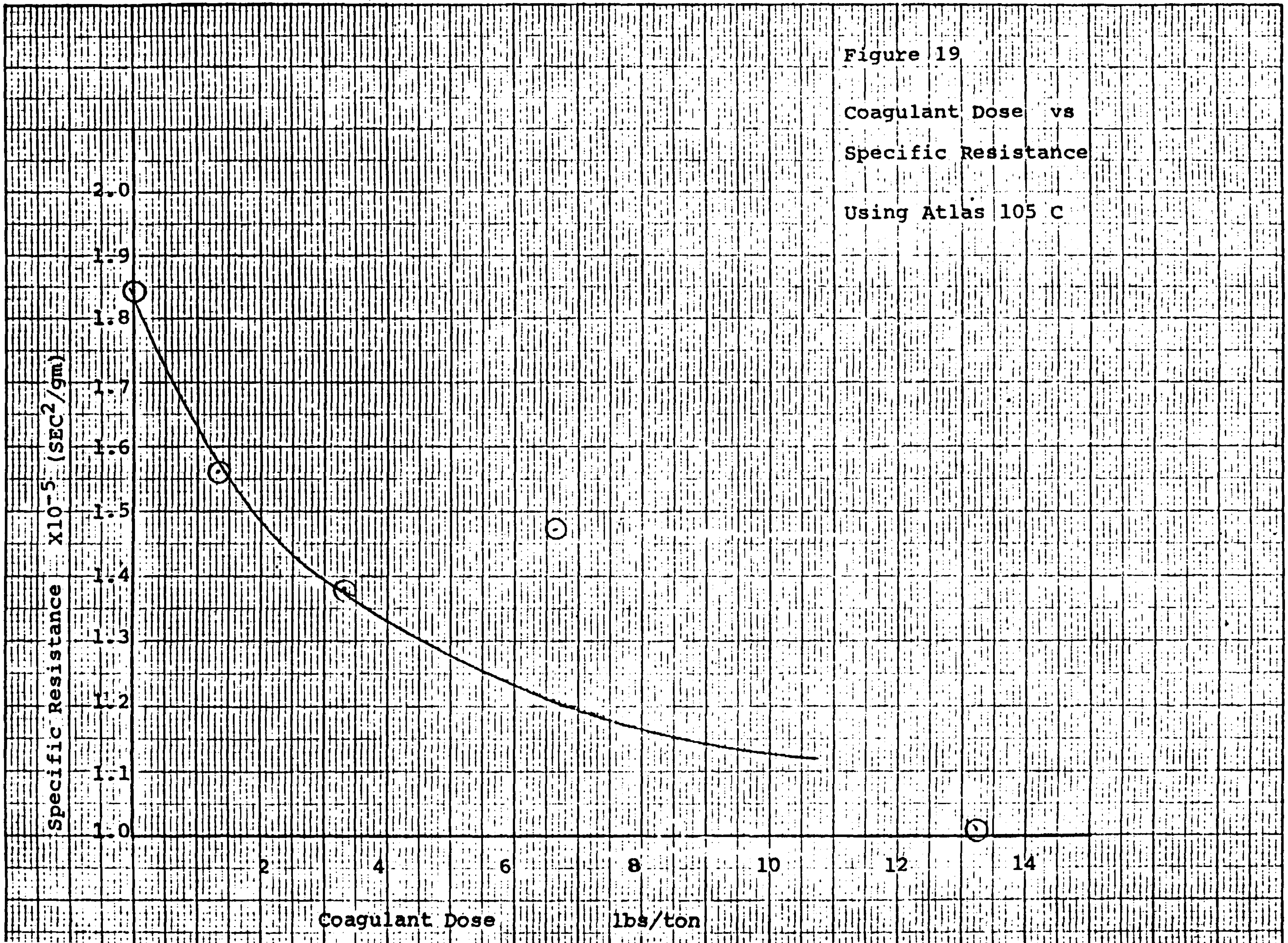


Figure 19
Coagulant Dose vs
Specific Resistance
Using Atlas 105 C
Specific Resistance X10-5 (SEC2/gm)
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
2
4
6
8
10
12
14
Coagulant Dose lbs/ton

THICKENER

Thickener Design

Discussion

The mathematical basis used to design a thickener is as follows:

$$\frac{C_u}{C_o} - 1 = \frac{K_b}{(ML)} n \qquad \text{equation (1)}$$

where

C_u = underflow concentration (lbs/ft^3)

C_o = feed solid concentration (lbs/ft^3)

ML = mass loading (lbs Solids/ft^2/Day)

K_b; n = experimentally determined constants

$\frac{KT}{K_b}$ = Scale up factor

The design calculations are summarized in Figures 23 through 24 , and Tables 56 & 57.Influent feed Solids is graphed versus the mass loading. Three different underflow values are shown; the design loading can be selected from this graph. The resulting overflow rate can be calculated from the equation:

$$OR = ML \; . \; 120 \; . \; \frac{C_u - C_o}{C_u}$$

where

OR = overflow rate gpd/ft^2
ML = mass loading lb/ft^2/day
Cu = underflow Solids - g/l
C_i = Influent Solids - g/l

Assuming a Solids generation rate of 78,000 pounds per day, a graph of influent Solids versus thickener diameter is shown (Figure 23). This graph was calculated from the mass loadings in Figure 24 . Thus, if the sludge settles to 5% in the chemical system clarifier and a 10% sludge is desired for dewatering, thickener 53 feet in diameter will be necessary.

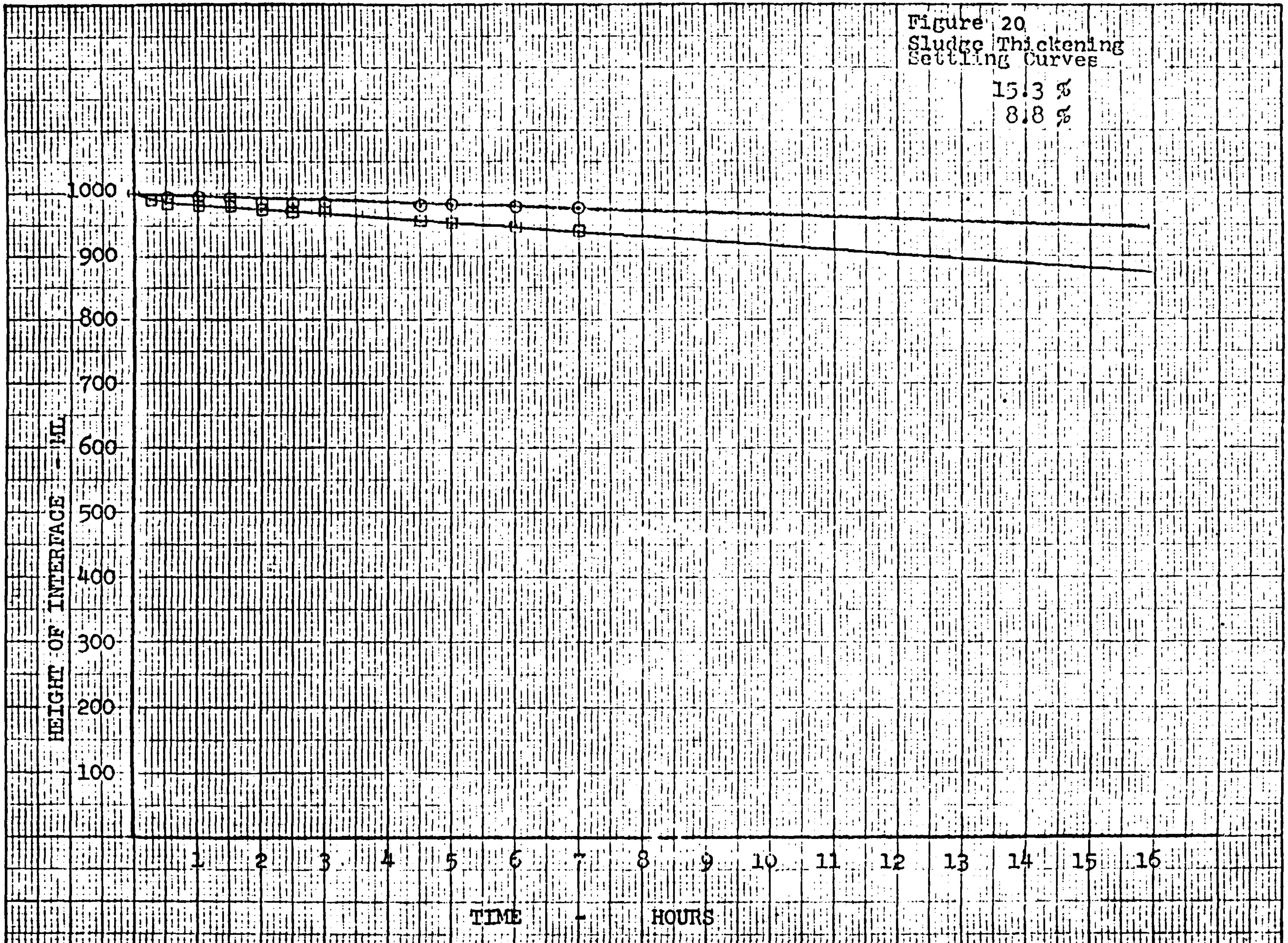


Figure 20
Sludge Thickening
Settling Curves

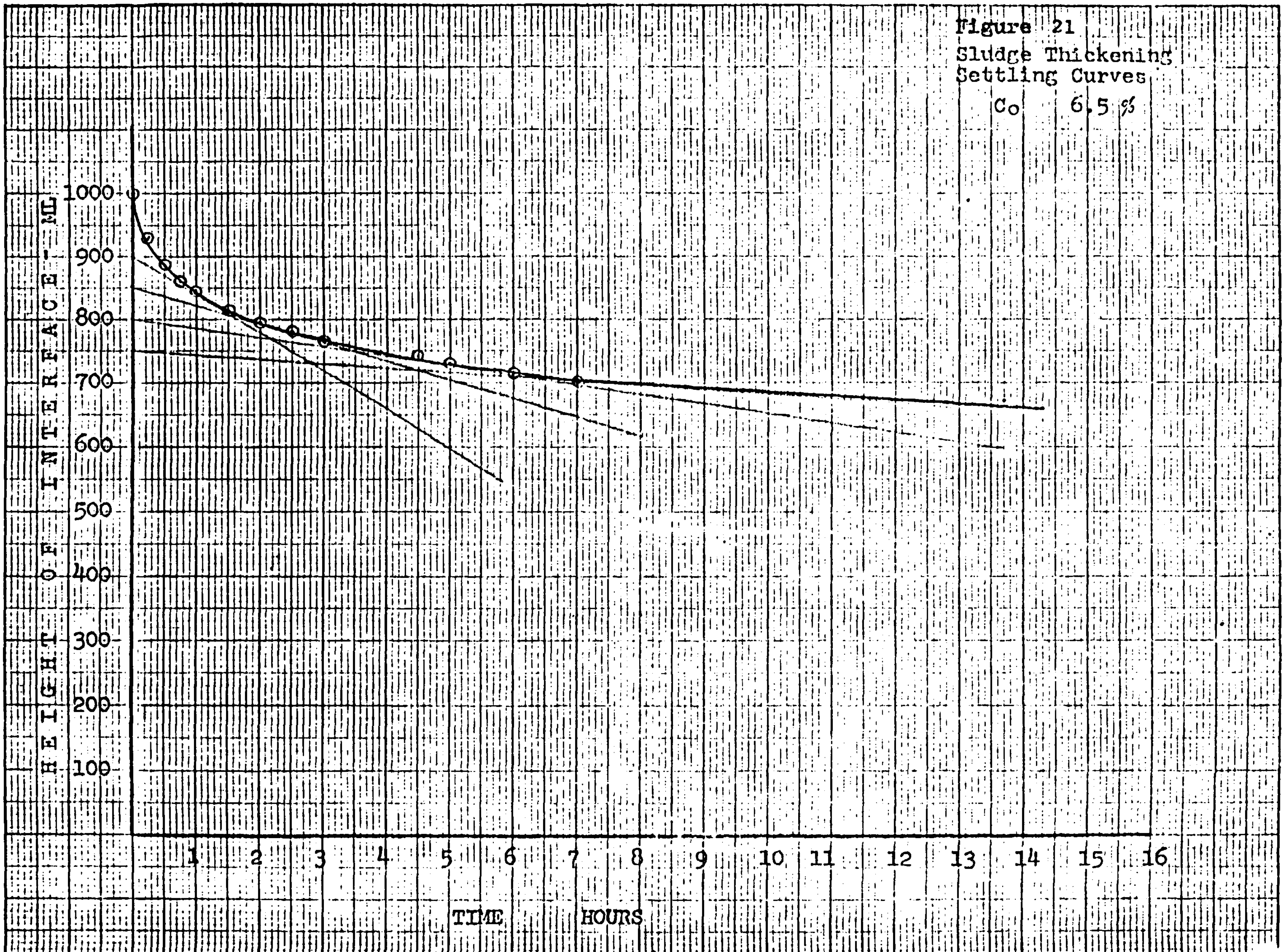


Figure 21
Sludge Thickening
Settling Curves
Co 6.5 %

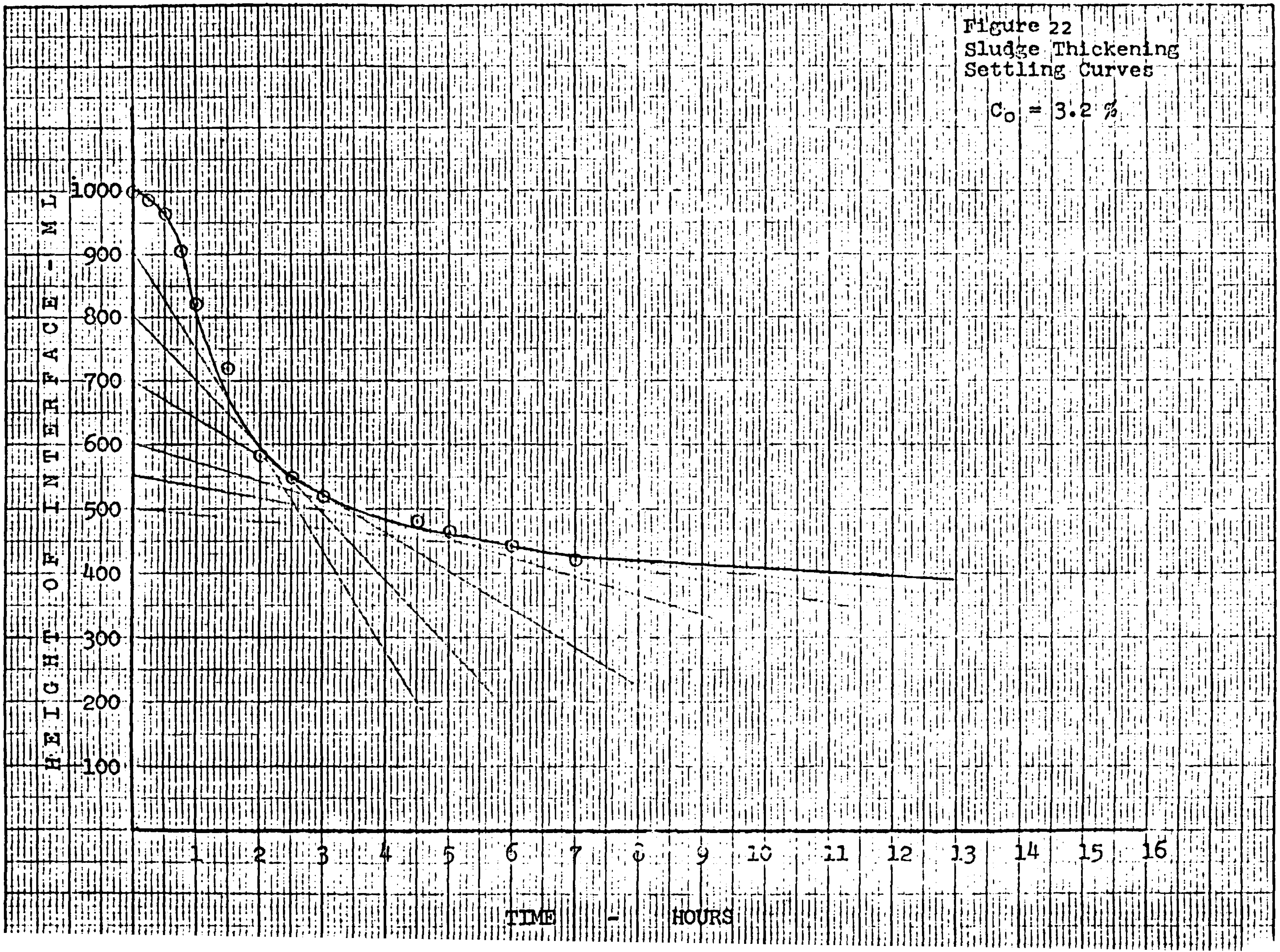


Figure 22
Sludge Thickening
Settling Curves

$C_o = 3.2\ \%$

TABLE 56

THICKENER DESIGN

UNIT AREA DETERMINATION

C_o = 65 g/l

H_i, ml	C_i g/l	C_i lbs/ft	V_i Ft/hr	Unit Area Ft^2/#/ Day: C_u = 80 g/l = 4.99#/ft^3	C_u = 100 g/l = 6.24#/ft^3	C_u = 150 g/l = 9.36#/ft^3
900	72	4.49	.0672	.0138	.0387	.0718
850	76.5	4.78	.0324	.0113	.0629	.131
800	81.2	5.07	.0165	-	.0934	.228
750	86.6	5.41	.0075	-	.136	.434

C_o = 32 g/l

H_i, ml	C_i g/l	C_i lbs/ft	V_i Ft/hr	C_u = 80 g/l	C_u = 100 g/l	C_u = 150 g/l
900	35.5	2.22	.1723	.0605	.0701	.083
800	40.0	2.50	.1142	.0728	.0875	.107
700	45.7	2.85	.0658	.0953	.121	.154
600	53.3	3.33	.0327	.127	.178	.246
550	58.2	3.63	.0200	.156	.24	.351
500	64.0	3.99	.0116	.180	.325	.516

TABLE 57

THICKENER DESIGN

n and K_b DETERMINATION

C_o	C_u	$\frac{C_u}{C_o}$	$\frac{C_o}{C_o} - 1$	Maximum Unit Area	MASS LOADING	K_b
65 g/l	80	1.23	.23	.0138	72.5	7.5
	100	1.54	.54	.136	7.35	
	150	2.31	1.31	.434	2.30	
32	80	2.5	1.5	.180	5.55	16.5
	100	3.12	2.12	.325	3.08	
	150	4.69	3.69	.516	1.94	

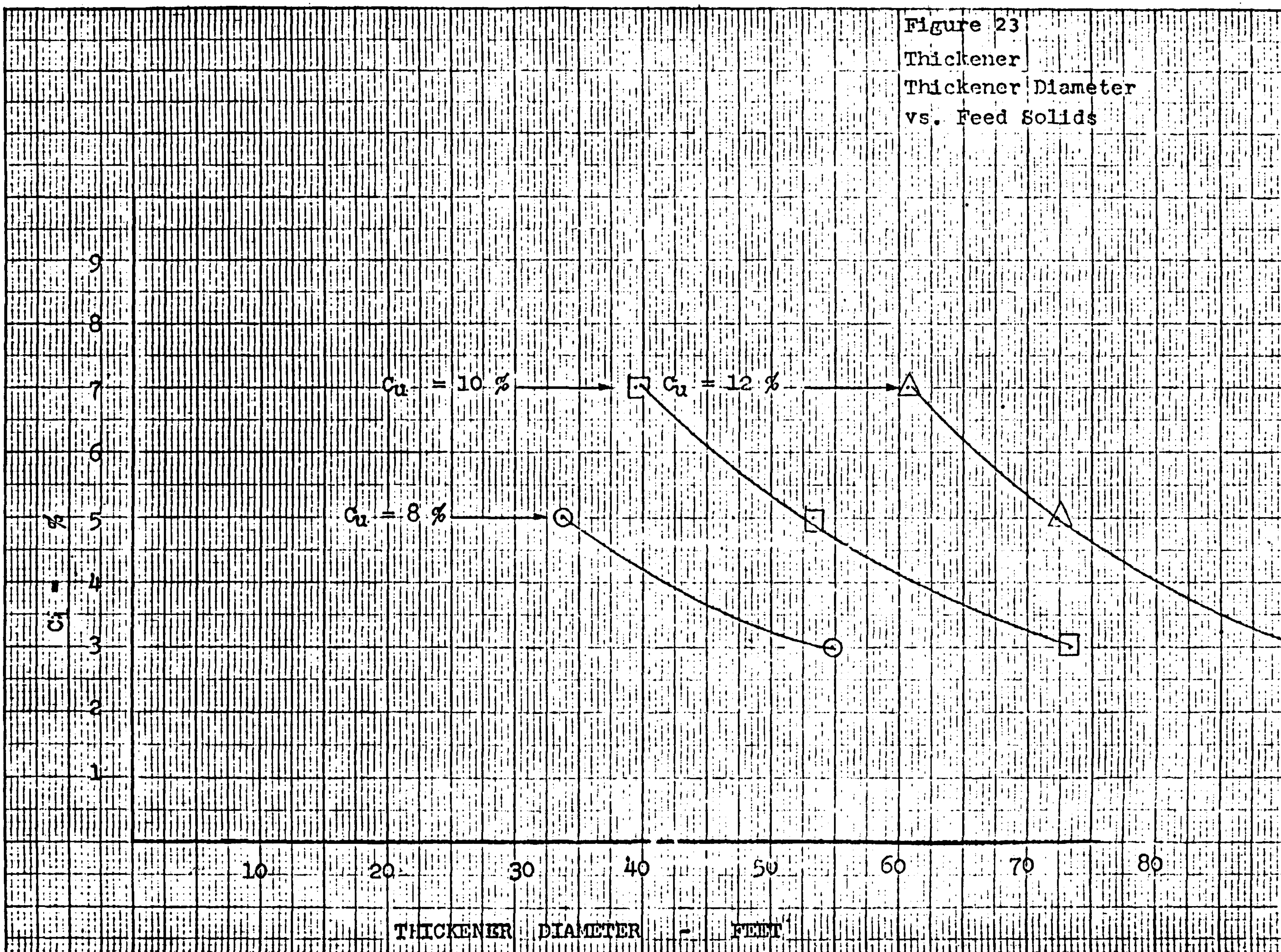


Figure 23
Thickener
Thickener Diameter
vs. Feed Solids
C_u = 10 %
C_u = 12 %
C_u = 8 %
C_i = %
1
2
3
4
5
6
7
8
9
10
20
30
40
50
60
70
80
THICKENER DIAMETER - FEET

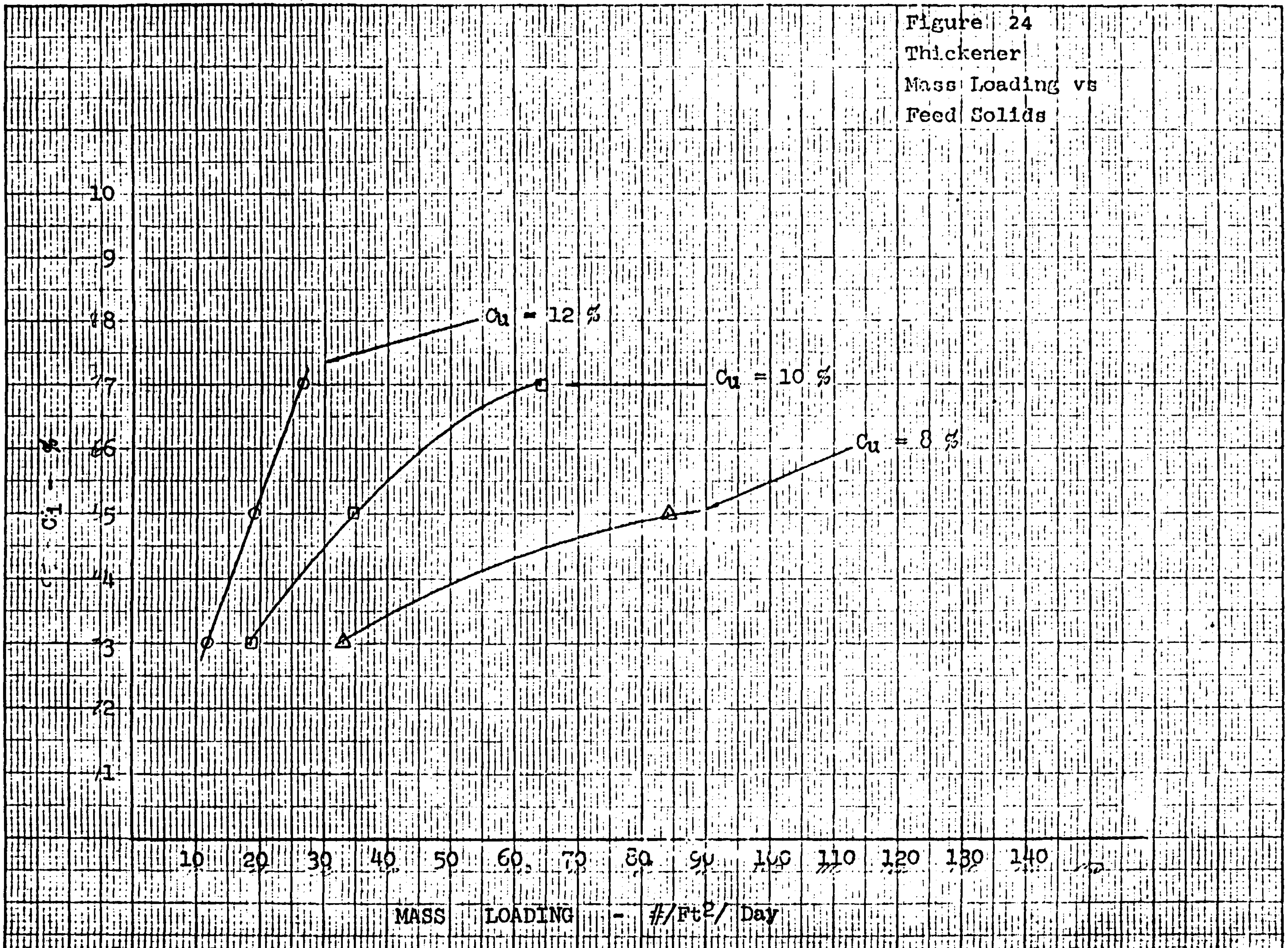


Figure 24
Thickener
Mass Loading vs
Feed Solids

CENTRIFUGATION

Centrifugation Experimentation

Objective: Evaluation of solids concentration performance of a centrifuge for dewatering lime sludge produced from treatment of the Sauget waste.

Sample for Testing: Sludge was withdrawn from the pilot plant clarifier. Operating conditions at the time were pH elevation of the waste to a pH of from 8.0 - 8.5 by addition of slaked high calcium quicklime. Flocculation utilizing Atlas 2A2 polyelectrolyte preceded clarification.

Feed sludge solids concentration was approximately 1.75% by weight.

Procedure: Sludge sample was held in 20 gallon tanks with agitators to assure uniform feed composition. The test unit was obtained from Centrifugal & Mechanical Industries, Inc., 146 President St., St. Louis, Missouri 63118. The centrifuge bowl capacity was two liters, 6" diameter, and had an operating speed of 3400 rpm.

$$\text{Centrifugal force} = 0.0000142\ (6")\ (3400)^2$$

$$CF = 980\ \frac{\text{lbsf}}{\text{lbm}}$$

Four different runs at feed rates of from 0.3 to 1 gpm were planned. Effluent and cake solids levels were measured.

The bowl has an opening in the bottom so that no water remained in the bowl at the end of a run to dilute the cake sample.

Results

Test results are listed in Table 58

Cake dryness will be no problem because at all flow rates (spin time decreasing with increasing flow), the cake was above 25% solids which will probably be an acceptable level for land fill disposal.

% solids capture vs. feed rate, has been shown in Figure 25 for the test unit and predicted for a 48" x 30" Bowl Sharples - Whirl-O-Matic solid bowl centrifuge.

For the 48" x 30" machine achieving 92% solids capture, 3 machines would be required.

TABLE 58

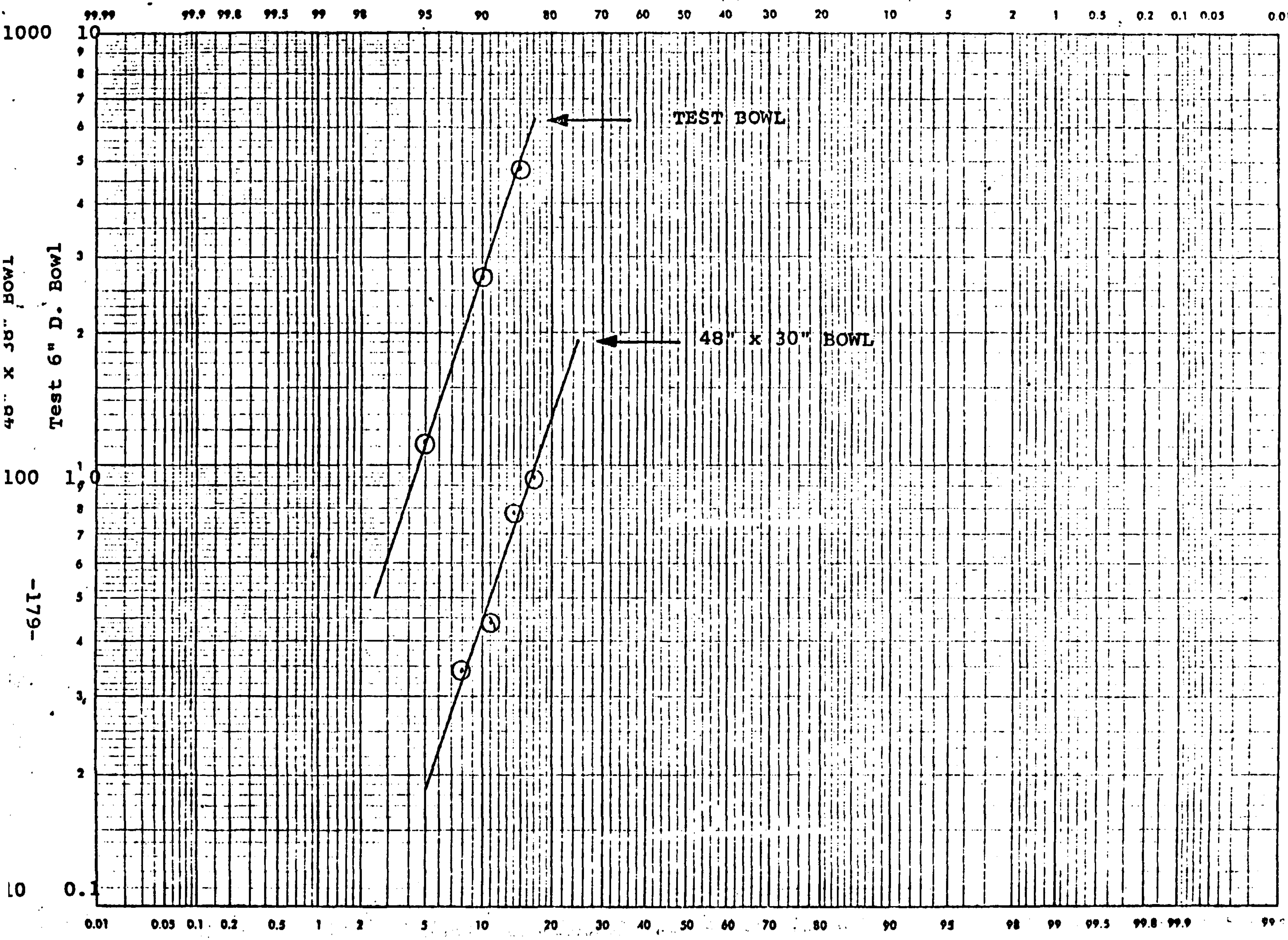
CENTRIFUGE EXPERIMENTS

	Exp.I(.3gpm)	Exp.II(0.46gpm)	Exp.III(0.81)	Exp.IV(1.01)
Feed rate, Initial	1,040 ml/min	1,860 ml/min	3,000 ml/min	3,920 ml/min
Feed rate, Average	.34 gpm	.44 gpm	0.78 gpm	0.94 gpm
eed, Final	1,280 ml/min	1,660 ml/min	3,120 ml/min	3,720 ml/min
pin Time	10 min.	5 min.	3 min.	2.5 min.
Gal. Processed	3.5 gal.	2.3 gal.	2.4 gal.	2.5 gal.
Vol. Sludge	0.1 gal.	0.1 gal.	0.2 gal.	0.3 gal.
Vol. of Eff.	3.4 gal.	2.2 gal.	2.2 gal.	2.2 gal.
Inf. T.S. & % Vol.	1.80%-14%	1.82%-14.6%	1.82%-14.6%	1.82%-14.6%
Inf. SS	1.76%	1.73%	1.73%	1.73%
.S. (by Diff)	0.04	0.09	0.09	0.09
Inf. D.S.% Volatile	14%	14%	14%	14%
Eff.T.S. & % Vol.	0.24%-32%	0.30%-28%	0.35%-26.4%	0.42%-25%
Eff.S.S. & % Vol.	0.14%-24%	0.20%-23%	0.24%-21%	0.31%-21%
.S. by Diff	0.10%	0.10%	0.11%	0.11%
Cake T.S. & % Vol.	27.4%-10%	28%-12%	32%-9.9%	32.1%-10.7%
Eff. Flow rate, Final	1,260 ml/min	1,640 ml/min	2,780 ml/min	3,400 ml/min
PM	3,400	3,400	3,400	3,400
. Removal Efficiency	92%	89%	86%	82%
.S. Removal Efficiency	87%	84%	81%	78%

VACUUM FILTRATION

Figure 25

% Removal vs. Feed Rate



DISCUSSION OF TEST WORK

The experimental data were obtained using a leaf test apparatus similar to that shown in Figure 26 , using the following experimental procedure:

A sample of sludge was obtained and the test leaf was submerged in the sludge for a specified form time. The test leaf was then removed and the leaf dried for a specified dry time by exposing the leaf to the air and maintaining the operating vacuum. The filtered sludge was then transferred to a tared weighing dish by applying a positive pressure ($\sim$ 2 psi).

The fabric used in all experimental runs was a cotton filter medium (CO-12, napped) supplied by the Eimco Corporation. The cotton medium was chosen for the following reasons:

1. Moderate alkalai resistance.
2. Cheapest available fabric ($/yd).
3. High organic solvent resistance.*

The following data were recorded (Table 59): Percent solids in the feed before and after the testing, the applied vacuum (P in inches of Hg), the form time (t_f), the dry time, the % cake solids, the cake thickness, the loading (L) lb/ft^2/hr), the volume of filtrate, and the suspended solids of the filtrate. Seven runs were made at different operating conditions as shown in Table 59 . Due to the high degree of experimental error involved with the test, each run was made three times and the data shown in Table 59 represents average values for the parameters measured.

* Although polypropylene is often recommended as a lime sludge filtration medium, the presence of benzene, toluene, etc., would make the cotton fabric the better choice for Sauget conditions. This choice was confirmed by a telephone conversation of March 21, 1972, with Mr. B. Dutson of the Eimco Corporation.

The following conditions were chosen as a basis for design:

Feed Solids: 10%

The expected underflow solids concentration from a low overflow rate clarifier or a thickener would be approximately 10%.

Applied Vacuum: 15 in H_g

Vacuums of 10 to 26 in. H_g are normally encountered in filtration operations. 15 in. was chosen for this operation.

Dry Time: 1.5 minutes

This was chosen on the basis of the data (Table 59). At dry times of 1.5 minutes, the thickest and highest cake solids concentrations were observed.

Submergence: 30%

Submergences normally encountered are between 15 and 40% usually at 33%. Thirty percent was selected for this case.

Form Time: 0.64 minutes

With a dry time of 1.5 minutes and a submergence of 30%, the total cycle time is 2.14 minutes, thus the form time is .64 minutes.

Cycle Time: 2.14 minutes

Filter Porosity

30 cfm/ft^2 at 0.5 inches of water. This is the porosity of the CO-12 cotton fabric.

The filter can be expected to deliver a filter cake of approximately 30% solids and the filtrate can be expected to contain less than 40 mg/l suspended solids. The volume of the filtrate can be calculated from a material balance:

Assuming 78,000 pounds of solids per day at 8% feed solids, the amount of water is 110,000 gallons, thus:

$$80{,}000\ (110{,}000) = 40\ (Z) + 300{,}000\ (Y)$$

where Z = the volume of the water in filtrate

Y = the volume of water in the discharge cake

$$110{,}000 = Z + Y$$

Thus solving for Z and Y, the amount of filtrate to be expected is 80,600 gallons per day, and 29,400 gallons per day can be expected in the discharge cake.

TABLE 59

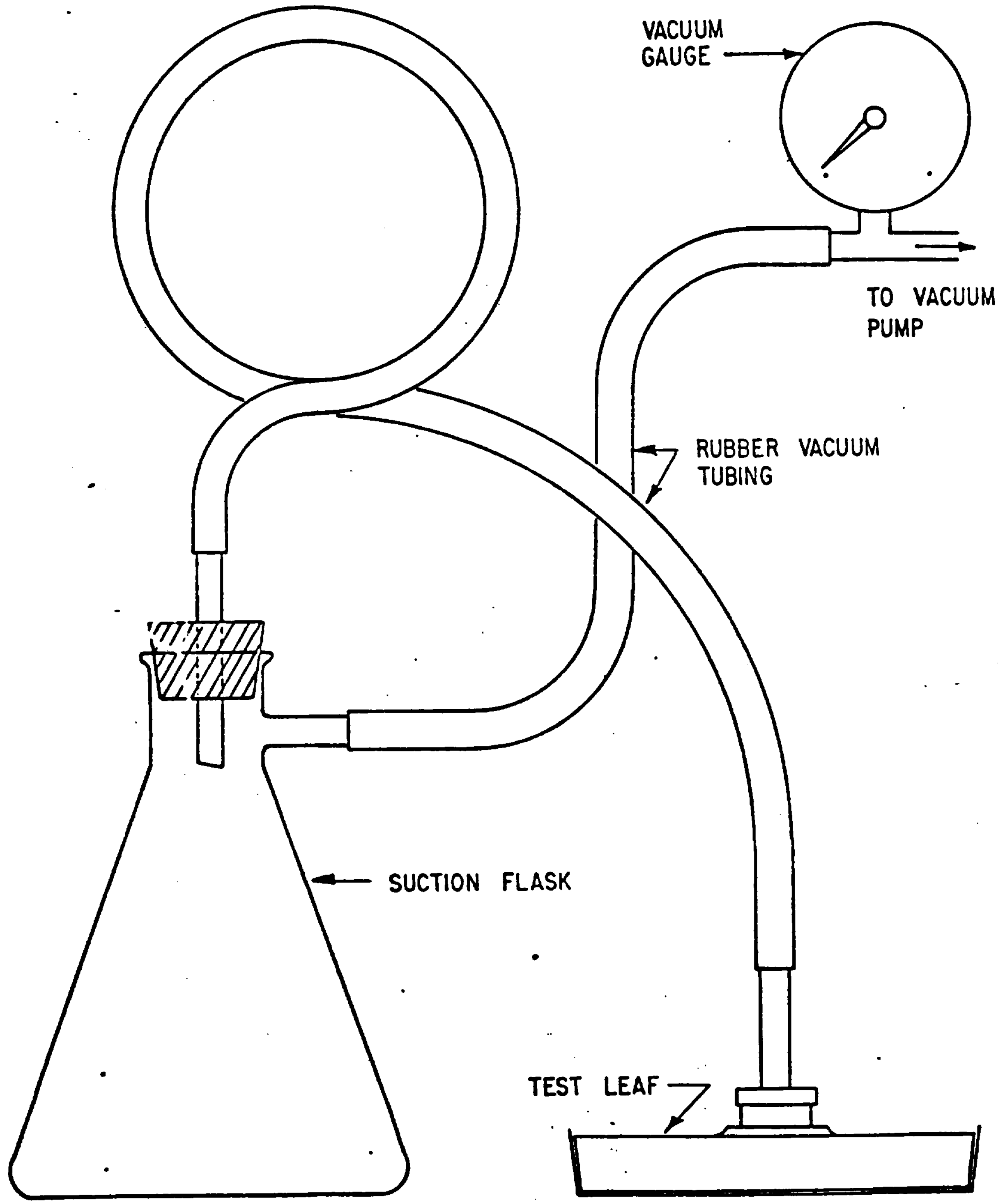
VACUUM FILTER

DESIGN DATA

Run No.	C_o % Solids in Feed	P Vacuum (in.Hg)	T_f Form Time min.	T_d Dry Time min.	Cake Solids %	Cake Thickness (in.)	L Loading #/ft²/hr	Volume Filtrate ml	Susp. Solids Filtrate mg/l
1	10.4	20	0.25	1.5	23.0	1/16"	3.35	54	76
2	10.4	20	0.50	1.0	33.2	3/16"	5.72	56	-
3	11.5	20	1.5	0.5	21.8	3/16"	9.0	62	5
4	10.0	20	0.5	1.5	33.4	1/16"	3.4	63	24
5	3.03	20	0.5	1.5	31.7	1/64	1.02	89	38
6	14.0	15	1.5	1.0	23.3	3/16	6.6	55	49
7	14.8	10	1.5	1.0	22.7	3/16	6.43	43	18

FIGURE 26

LEAF TEST APPARATUS



APPENDIX VII

SULFIDE TESTING

DISCUSSION OF TEST WORK

The ability of the proposed treatment system to meet the State heavy metals criteria was of major concern during the pilot plant studies. Table 60 shows the State effluent standards proposed on May 19, 1971 which differ considerably from those adopted on January 6, 1972.

It was felt that the standards proposed on May 19, 1971 would be extremely difficult, if not impossible to meet with lime neutralization and metal hydroxide precipitation, as is indicated by the average values of 0.12 and 0.41 mg/l for copper and manganese respectively in the chemical system effluent. These values would not have met the criteria proposed at the time. The precipitation of the much more insoluble heavy metal sulfides was therefore explored to determine whether the proposed effluent standards could be met with such a system*. Table 61 compares the solubilities of several heavy metal sulfides, hydroxides and carbonates. As may be seen, the sulfides are substantially less soluble compounds in most cases.

A sulfide precipitation step was therefore studied on a pilot scale using a reactor - clarifier with sodium hydrogen sulfide addition and a collection tank (see Drawing No. 3-11).

Chemical system effluent containing approximately 4.3×10^{-6} moles/liter of metals was fed to the sulfide reactor - clarifier at a flow rate of 0.57 gpm (equivalent to an overflow rate of 120 gal/day/ft^2). A large molar excess of sulfide was maintained in the waste stream to force the sulfide equilibrium to favor precipitation (see operating data Table 62).

Day to day heavy metals reductions were observed in the sulfide system effluent. (See Table 63). However, as summarized by the following average values, it was shown that sulfide treatment had little effect on the average effluent metals levels:

	Before Treatment	After Treatment
Zn	0.1	0.067
Cu	0.17	0.12
Cd	0.01	0.01

The system did show reasonably consistent and sometimes substantial copper reductions.

*As is indicated in Table 60 , the adopted standards are substantially less stringent and can be met by the proposed chemical treatment system without added chemical (sulfide) addition costs.

Suspended solids data during the period of operation of 8/15 through 8/29/71 (see Master Data Tables and) show two upset periods, the first on 8/20 and the second on 8/28. Removing these upset periods, the suspended solids averaged 44 mg/l in the feed and 23 mg/l in the effluent.

It is felt that a major reason for poorer than expected performance of this sytem was resulted from the formation of very small precipitate particles (due to the very low influent metals concentrations). These particles would be very difficult to remove by gravity sedimentation. Therefore, even though the metals may have been removed from the waste stream. In addition, the sulfides of mercury, arsenic, antimony and tin can be redissolved in solutions containing excess sulfide. Others metals (Cu, Ag, Bi, Cd, Pb, Zn, Co, Ni, Fe and Mn) are not subject to resolublizing by complex ion formation.

TABLE 60

PROPOSED VS ADOPTED STANDARDS

STANDARD PROPOSED 5/19/71

CONSTITUENT	DATE OF COMPLIANCE FOR CONCEN. (mg/l) SHOWN 7/1/71	7/1/72
Arsenic* (Dissolved)	1.0	0.05
Barium* (Dissolved)	5.0	1.0
Boron (Dissolved)		1.0
Cadmium* (Dissolved)	0.05	0.01
Chloride		250.0
Chromium-Trivalent* (Dissolved)	1.0	
Chromium-Hexavalent* (Dissolved)	0.05	
Copper* (Dissolved)	0.1	0.04
Cyanide	0.025	
Flouride		1.0
Iron* (Total)	10.0	
Iron* (Dissolved)		0.3
Lead* (Dissolved)	0.1	0.05
Manganese* (Dissolved)	0.05	
Mercury* (Total)	0.0005	(effective date
Nickel* (Dissolved)	2.0	3/25/71-R70-5)
Oil (Hexane Solubles)	15.0	10.0
pH	range 6 to 10	6 to 9
Phenols	0.2	0.1
Selenium* (Dissolved)	0.01	
Silver* (Dissolved)	0.05	
Total Solids (Dissolved)	750.0	
Zinc* (Dissolved)	1.0	

*HEAVY METALS (See note 1)
(1) The total concentration of all dissolved heavy metals in any effluent shall not exceed 2.0 mg/l after July 1, 1972.

STANDARD ADOPTED 1/6/72

CONSTITUENT	CONCENTRATION (mg/l)
Arsenic (total)	0.25
Barium (total)	2.0
Cadmium (total)	0.15
Chromium (total hexavalent)	0.3
Chromium (total trivalent)	1.0
Copper (total)	1.0
Cyanide	0.025
Flouride (total)	2.5
Iron (total)	2.0
Iron (dissolved)	0.5
Lead (total)	0.1
Manganese (total)	1.0
Mercury (total)	0.0005
Nickel (total)	1.0
Oil (hexane soluble or equivalent)	15.0
pH range	5 to 10*
Phenols	0.3
Selenium (total)	1.0
Silver	0.1
Zinc (total)	1.0
Total Suspended Solids (from sources other than those covered by Rule 404)	15.0

*The pH limitation is not subject to averaging and must be met at all times.

TABLE 61

SOLUBILITY OF METAL HYDROXIDES, SULFIDES AND CARBONATES

	SULFIDE		HYDROXIDE		CARBONATE	
	Literature Solubility mg/l	Solubility Product	Literature Solubility mg/l	Solubility Product	Literature Solubility mg/l	Solubility Product
Cd^{+2}	1.3	$3.6x10^{-29}$	2.3	--	(2)	--
Cu^{+1}	$1x10^{-14}$	$2x10^{-47}$	(2)	--	(2)	--
Cu^{+2}	0.33	$8.5x10^{-45}$	(2)	--	(2)	--
Fe^{+2}	6.2	$3.7x10^{-19}$	6.7	$1.6x10^{-16}$	67	--
Fe^{+3}	(3)	--	--	$1.1x10^{-36}$	--	--
Pb^{+2}	124	$3.4x10^{-28}$	155	--	1.1	$3.3x10^{-14}$
Mn^{+2}	4.7	--	2	$4x10^{-14}$	65	--
Mn^{+3}	6	--	(3)	--	--	--
Hg^{+1}	(2)	--	--	--	0.45	--
Hg^{+2}	.01	$2x10^{-49}$ $4x10^{-53}$	--	--	(2)	--
Ni^{+2}	3.6	$1.4x10^{-24}$	13	--	93	--
Zn	6.9	$1.2x10^{-23}$	.0026(1)	$1.8x10^{-14}$	10	--

(1) Amphoteric

(2) Insoluble

(3) Very slightly soluble

TABLE 62

OPERATING DATA - SULFIDE EXPERIMENT

Date	Flow to Sulfide Reactor (gpm)	Sulfide Flow (ml/min)	Sulfide Conc. in Solution (mg/l)	Sulfide Molarity $\times 10^6$	Moles/liter of Metals to be Removed. $\times 10^6$	Molar Excess $\times 10^6$
8/14	0.58	10	35.6	634	4.27	630
8/15	0.58	9	32.2	574		570
8/16	0.50	9.5	39.4	702		698
8/17	0.50	9	37.4	666		662
8/18	0.60	10	34.6	617		612
8/19	0.63	10	33.0	588		582
8/20	0.47	10	44.2	788		782
8/21	0.47	10	44.2	788		782
8/22	0.69	10	30.1	536		532
8/23	0.63	10	33.0	588		584
8/24	0.55	9	34.0	606		602
8/25	0.50	11	457	815		811
8/26	0.55	11	41.5	740		736
8/27	0.60	10	37.4	666		662
8/28	----	16	----	---		---
8/29	----	10	----	---		---
8/30	0.65	10	31.9	569		565
	0.57	9.9	34.0	658	4.27	654

TABLE 63

PILOT PLANT

SULFIDE ADDITION EXPERIMENT

METHOD: SOLVENT EXTRACTION

Date	Raw Influent Zn (ppm)	Raw Influent Cu (ppm)	Raw Influent Cd (ppm)	Chemical System Effluent Zn (ppm)	Chemical System Effluent Cu (ppm)	Chemical System Effluent Cd (ppm)	Sulfide Treated Effluent Zn (ppm)	Sulfide Treated Effluent Cu (ppm)	Sulfide Treated Effluent Cd (ppm)
8-14-71				0.10	0.190	N.D.	0.13	0.06	<0.01
15				0.10	0.14	N.D.	0.15	0.065	<0.01
16				-	-	-	<0.01	0.095	0.026
19				<0.1	0.6	0.022	<0.01	0.330	0.014
20				<0.1	0.082	0.010	<0.01	0.072	<0.01
21				<0.1	0.240	0.010	<0.01	0.250	<0.01
22				-	-	-	<0.01	0.160	<0.01
23				<0.1	0.205	0.008	<0.01	0.140	<0.01
24				0.1	0.08	0.016	<0.1	0.06	0.010
25	7.8	3.2	0.16	<0.1	0.11	N.D.	0.1	0.05	<0.01
26				<0.1	<0.05	N.D.	<0.1	0.15	<0.01
27				<0.1	0.14	N.D.	<0.1	0.05	<0.01
28	5.2	1.7	0.02	<0.1	0.04	N.D.	<0.1	0.05	<0.01
29				0.1	0.25	N.D.	<0.1	0.08	<0.01
30	2.7	1.7	0.02	<0.1	0.13	N.D.			
Avg.	5.23	2.20	0.07	<0.1	0.17	0.01	.067	0.12	<0.01

Note: Detection Limits
Zinc - 0.1
Copper - 0.01
Cadmium - 0.01

MASTER DATA
CHEMICAL SYSTEM EFFLUENT

Day No.	Date	pH	Temp. (°F)	BOD5*	COD5*	Total Solids*	Susp. Solids*	% Volatiles	Dissolv. Solids*	Phenols*	Free Chlorine*	Total Chlorine*	Phosphate*	Color(APHA)
79	7/29	8.0			323		27	37						
80	7/30	8.0			296									
81	7/31	7.8			434									
82	8/1	7.9			333									
84	8/3	7.5			344		16	38						
85	8/4	8.4			318		10							
87	8/6				344		131	43						
88	8/7				306									
89	8/8				405									
91	8/10													
92	8/11	6.2			340		51	42						
93	8/12	10.9			318		113	22						
94	8/13	8.0			300		36	15						
95	8/14	8.4			330		11	100						
96	8/15	9.4			360		9	89						
97	8/16	9.2			404	5424	20	30	5404					
98	8/17	8.7			200		14	50						
100	8/19	9.9			246		94	57						
101	8/20	10.9					137	34						
102	8/21	8.5			286		49	39						
103	8/22	7.4			259		93	29						
104	8/23	8.3			251		75	17						
105	8/24	8.8			354	4191	48	0	4143					
106	8/25				393									
108	8/27	8.2			282		26	34						
109	8/28	11.3			318		116	18						
110	8/29	8.8			311		10	40						

*Values Reported in mg/l.

MASTER DATA
SULFIDE SYSTEM EFFLUENT

TABLE 65

Day No.	Date	pH	Temp. (°F)	BOD5*	COD5*	Total Solids*	Susp. Solids*	% Volatiles	Dissolv. Solids*	Phenols*	Free Chlorine*	Total Chlorine*	Phosphate*	Color (APHA)
1	8/15				332		9	09						
2	8/16				336		18	22						
3	8/17				303		13	31						
4	8/18													
5	8/19	9.5			310		29							
6	8/20	10.7			403		186	6						
7	8/21	8.0			328		63	19						
8	8/22	8.6			266		20	50						
9	8/23	8.4			348		29	28						
10	8/24	8.8			277	4313	17	0	4296					
11	8/25				424									
13	8/27	8.6			301		15	73						
14	8/28	11.2			315		115	16						
15	8/29	8.8			335		14	21						

*Values Reported in mg/l.

APPENDIX VIII

SULFIDE SLUDGE TESTING

SULFIDE SLUDGE TESTING

As part of the sulfide precipitation experimentation, sludge sedimentation testing was conducted. Table 66 shows the data obtained: sludge interface height versus time for several different initial (C_o) concentrations. The sludge tested was a mixture of the lime and sulfide sludges which would be expected from a commercial facility with sulfide precipitation and lime neutralization.

TABLE 66

ZONE SETTLING - CONDITION: LIME SLUDGE WITH POLYMER AND SULFIDE

t_1 (min)	Co=460 mg/l	Co=830 mg/l	Co=1230 mg/l	Co=1520 mg/l	Co=2360 mg/l	Co=3080 mg/l
0	1000	1000	1000	1000	1000	1000
1	990	990	990	990	990	990
2	So thin	930	930	930	900	900
3	it is im-	900	900	900	850	850
4	possible	550	600	600	500	600
5	to see set-	450	500	500	450	500
6	tling dur-	300	400	400	300	300
7	ing the 1st	200	300	300	150	250
8	few minutes	100	200	200	100	200
9	<10	40	50	50	50	75
10	<10	15	25	30	50	70
11	<10	15	25	30	50	65
12	<10	15	25	30	45	65
13	"	"	"	"	"	50
14	"	10	20	25	45	60
15	"	"	"	"	40	55
16					40	55
17					40	55
18					40	55
19					40	55
20					40	50
22						
24						
26						
28						
30						

Supernatant contained black particles
and was very turbid.

APPENDIX IX

ANALYSIS OF BIOLOGICAL TREATMENT INVESTIGATION DATA

Previous Biological Treatability Studies

Analysis of Village Waste Stream

Examination of Compounds Present
BOD_5 Data

Effects of Chlorine on Biological Treatment of the Waste

Biological Treatability Studies

Aeration Experiments

PREVIOUS BIOLOGICAL TREATABILITY STUDIES

During the late fifties, work was conducted by Metcalf and Eddy on treatment of the waste waters from the Village of Sauget. (Table contains data on waste composition.) The pilot plant activated sludge system demonstrated that the organic content of the waste as represented by BOD_5 could be reduced from an average level of about 300 mg/l down to a level between 50 and 100 mg/l and that phenols could be reduced from a level of about 50 mg/l down to 4 mg/l. The retention time necessary for this BOD_5 reduction in the aeration chamber was found to be between 20 and 24 hours. The entire system flow scheme determined at that time has been shown in Figure . It should be noted that preaeration took place in the neutralization tank and that in recent studies stripping by air was found to be the primary mechanism for removal of organic contamination.

Since the study was conducted in 1959, a number of changes in the plant operations throughout the Village have taken place which would effect the performance of a biological system. The changes are as follows:

1. Mobil Oil has shut down their operations. The Metcalf and Eddy report of 1960 noted that the Mobil Plant was a major contributor of phenol and BOD_5.

   Their contribution does not appear to have been particularly significant in 1959 - 3.4% of the phenol and 3.2% of the BOD_5. However, the 1959 BOD_5 and phenol levels are probably low. This observation is made because the 1959 phenol material balance results for the total from the Village and the total from Monsanto and Mobil, the two major contributors, do not balance. The quantity of phenol in Monsanto's waste, 9700 lbs/day, is probably correct because it was determined from samples collected on a routine sampling program while only spot-checks were used at Mobil. The present 1971 data also supports the 9700 lbs/day quantity. Phenol and BOD_5 numbers at Mobil ranged from 18 to 385 mg/l and 165 - 1530 mg/l respectively. Analysis of all the data available shows a significant reduction in phenol and BOD_5 since 1959.

2. Monsanto shut down its phenol department in October of 1970 and with other in-house waste flow reductions have accounted for a large reduction in phenol losses from the 1959 waste level. Phenol could have theoretically contributed over 30% of the total BOD_5 load from the Village found in 1959.

14,700 lbs phenol/day (1959)	1000 lbs phenol/day (1971)

3. Monsanto shut down its alkyl benzene department and Santomerse department which should have been been noted as reduction in the COD load between 1959 and now.

4. ACl has been added as a new department at Monsanto, which has a waste load over 1959 levels of 10,000 lbs/day of chlorine. If the loss were continuous it would be equivalent to a chlorine concentration of 50 mg/l in the Village effluent. However, both chlorine and CYA are not continuously discharged.

5. Hydrogenation output from Monsanto's Department 247 has increased by about 200% over the last 10 years based on estimates by Krummrich personnel. This Hydrogenation department waste load theoretically accounts for approximately 20% of the present total COD load discharge by the Krummrich plant.

6. Monsanto's Department 255 (4-nitrodiphenylamine) was started up during 1964 and 1965, and Department 255 now accounts for almost 10% of the present total COD from the Krummrich plant.

It is apparent that there has been an increase in the refractory type compounds in the Krummrich waste with a significant decrease in the more readily degradable unsubstituted phenol wastes.

ANALYSIS OF VILLAGE OF SAUGET WASTE STREAM - 1971

Examination of Compounds Present

Monsanto and Edwin Cooper contribute the majority of the organic contaminants to the Village waste treatment facility. Before Edwin Cooper's acquisition of the North area of the Monsanto plant, analyses were run on composite samples from the Krummrich plant by Monsanto personnel.

The predominant class of compounds found by the analysis of the waste were substituted aromatics, i.e., nitrated and chlorinated phenol, benzene, and aniline. It is known that the method used may not detect all waste components because of the method of extraction. Xylene, for example, is known to be present but was not indicated in the results.

BIOCHEMICAL OXYGEN DEMAND DATA

Raw waste BOD_5 data from the period from 10/27/70 - 12/31/70 and 5/30/71 - 7/21/71 has been analyzed recognizing that apparent inhibition did exist. The most drastic example of the waste inhibition was observed on 7/8/71 and the data have been plotted in Figure 28. For analysis purposes the data were plotted for dilutions from 0.1 to 8% for the periods mentioned above and it was noted that at 2% only one value was observed over 200 mg/l, at 1% two values, and at 0.1 to 1% there were six values over 200. In order to obtain an adequate dissolved oxygen depletion in the BOD_5 bottle it was necessary to routinely set up dilutions at from 0.5 to 4%. Values obtained from a dilution of 2% or less were used in the frequency distribution analysis shown in Figure 34.

$$\bar{x} = 100 \text{ mg/l } BOD_5$$
$$\sigma = 50 \text{ mg/l}$$

The raw waste would be expected to exhibit inhibition because of the heavy metals present. Even after neutralization, however, some degree of inhibition did exist. Data for 5/26/71 have been shown in Figure 29 . For a sample taken after neutralization and sedimentation, the BOD_5 ranged from 50 to 320 mg/l for dilution from 8 to 2% respectively. The chemically-treated effluent however was still inhibitory as indicated by the decrease in the BOD_5 value from 2 to 8% dilution. Bio-effluent did not exhibit this inhibition in the BOD_5 test.

On 7/8/71 (note Figure 28) the raw waste was quite toxic. Data for samples taken after chemical treatment, biotreatment, carbon treatment, and air stripping have been shown in Figure 30 . Because the carbon column effluent, with a COD of only 64, exhibited some degree of inhibition in the BOD_5 test, the inhibition may be attributed not only to heavy metals or organics but possibly to some other inorganic constituents.

On 6/1 (note Figure 31) after chemical treatment the effluent BOD_5 measured at dilutions from 8 to 2% ranged from a value of 38 to 163 mg/l. After biotreatment and carbon treatment, the BOD_5 data does not indicate as pronounced an effect of dilution on BOD_5, but one does apparently still exist.

Data from 6/4 has been shown in Figure 32 . These data are probably more typical of the normal observations with inhibition exhibited in the raw waste test but not apparent after chemical treatment. (Note data for 6/14 in Figure 33 .)

The BOD_5 data for the chemical system effluent at different dilutions for the period from 5/30/71 to 7/21/71 was analyzed. It was noted that values at 4% dilution or greater indicated inhibition. Values obtained at dilutions of 4% or lower were used in the frequency distribution analysis shown in Figure 35 . The distribution is not normal but a forced fit would yield:

$$\bar{x} = 90 \text{ mg/l } BOD_5$$
$$\sigma = 30 \text{ mg/l } BOD_5$$

EFFECTS OF CHLORINE

Chlorine may affect a biological system in a number of different ways:

1. Chlorinating certain organics thus making them more difficult to degrade.

2. Chlorinating certain compounds to such an extent that there could be an increase in the rate of biodegradation because of change in structure (i.e., break ring structure).

3. May be present in concentrations which would be toxic to a biological system.

The following discussion has been taken from the American Petroleum Institute's Manual on Disposal of Refinery Wastes.

"Chlorine, hypochlorites, and chlorine dioxide are capable of oxidizing a wide variety of organic compounds. Chlorine also reacts with ammonia to form chloramines which react less rapidly, but are stronger oxidants than chlorine alone . . . complete oxidation of ammonia by chlorine requires a Cl_2/NH_3 ratio of about 10/1. Chlorine will oxidize ammonia before reacting with phenols.

"The theoretical ratio of chlorine to phenolics required for complete destruction is approximately 6/1 . . .

"Despite the potential for formation of chlorophenolics, chlorine or hypochlorites can be used to completely oxidize phenolics under proper conditions. If the final pH after chlorination is less than 7, production of chlorophenolics predominates. If greater than 7, oxidation and destruction of phenolics occur . . ."

In summary, requirements for complete destruction of phenolics are:

1. Temperature must be below 110°F before chlorine is added; otherwise chlorates will be formed.

2. pH of the waste must be kept at 7 or higher to prevent formation of chlorophenolics.

3. Reaction must be continued for a sufficient period of time - generally 1 hour to 2 hours. Chlorination stepwise or in series has been used with some success in operations where such retention time was difficult to attain.

Considering the information above and the fact that the Village waste is normally acidic, it is felt that the chlorine present in the waste will both increase the difficulty of waste biodegradation, and could increase the waste toxicity by formation of chlorinated ring compounds.

Whether or not chlorine would affect a biological treatment system can probably best be answered by examining the maximum possible chlorine concentration after a dump and calculating the concentration in a complete mix system. Based on calculations by Krummrich personnel, the concentration of chlorine could reach a level of 440 ppm for a 30-minute period. In the Village waste at this 440 ppm level, the level in a lagoon or tank with 12 hours' retention time would be 18 mg/l and the level in a 24-hour retention time lagoon would be 9 ppm. Because of the reaction of the chlorine with the waste components, it is doubtful that during normal operation these toxic levels would be seen in a biological system. However, with large dumps of ACl it might be possible. As can be seen by data on the Village waste, periodic peaks were observed with levels so high that sampling the waste was hazardous. (Note Table 68).

BIOLOGICAL TREATABILITY STUDIES

From an examination of the Village of Sauget waste for specific components, it was observed that there are many aromatics which are very resistant to biochemical degradation. The raw waste after neutralization and sedimentation exhibited inhibitory effects at certain times in BOD_5 tests at different sample dilutions. It is not clear from the data whether this can be attributed to organic constituents or some inorganic constituents or both.

The BOD_5 of the waste after the chemical treatment averaged about 90 mg/l.

FILL AND DRAW UNITS

The first step to evaluate biological treatment was to have our field personnel attempt to acclimate a domestic activated sludge seed to the Village of Sauget waste.

The first method used was a fill and draw batch system consisting of a two liter aerated graduated cylinder with agitation provided by use of a magnetic stirring bar.

The first tests on the Sauget effluent involved feeding two batch aeration units neutralized effluent. Unit II was fed caustic neutralized unclarified waste and Unit III caustic neutralized clarified waste.

The units were started using a domestic seed on 10/23/70. The feeding schedules for the two units have been listed in Tables 70 and 71 along with the mixed liquor solids level.

On 11/11/70 two treatability studies were conducted. The basic procedure used has been shown on Table 69.

On 12/15/70 another treatability study was run using lime as a neutralizing agent and clarifying the waste before feeding to the batch unit (Unit V). In Table 72 the data for the unit during the acclimation period has been shown. It should be noted that the solids level dropped after adding domestic sludge to the system.

BATCH RESULTS

Note the July 21, 1971 laboratory report for a discussion of biological treatment. Data analysis for the batch studies using a conventional kinetic approach is not completely valid because of the air stripping of organics.

The results from the treatment of the total Village Effluent in Units II, III and V have been shown in Tables 73- 75, and plotted in Figures 36 - 41. Data indicates that some portions of the waste are degradable, but the loading are at such a low level ($\sim$0.05gm BOD_5/gm VMLSS) that the system was starving.

Essentially no color removal was achieved at either retention times would be expected from past experience and a survey of the literature.

TABLE 69

BATCH TREATABILITY PROCEDURE

1. Acclimate sample (effluent COD's are stable, solids are stable to building) in a 2 liter fill and draw (Batch) unit.

2. Sample raw feed on test day and run COD and BOD tests.

3. Settle mixed liquor in the batch unit for 30 min., and siphon off as much effluent as the amount to be fed.

4. Add raw (Neutralized & Nutrified) waste, and turn on the mixer and air.

5. Immediately draw off 100 ml mixed liquor. This is placed in a 100 ml graduated cylinder and settled for 30 min. The supernatant is then decanted and BOD and COD tests are run. The mixed liquor O_2 uptaken is taken immediately after the 100 ml for settling is drawn off. (Method: D.O. recorded every 30 sec. for 5 min. O_2 uptake in mg O_2/l/hr. computed from readings between 1 min. and 4 min.) The pH of the mixed liquor, suspended solids and % volatile are run.

6. Step 5 is repeated at time: 30 minutes, 1 hour, 2 hours, 3 hours, 4 hours, 8 hours, 12 hours, 24 hours, and 48 hours.

7. Compile data.

8. Rates of BOD, COD and solids reactions can be observed.

9. Graph: BOD (mg/l) vs. time to find rate of this reaction, and the values $\frac{d\ BOD}{d\ time}$ which are used in the Brower equations for estimating detention time in a continuous flow unit.

CONTINUOUS FLOW EXPERIMENTS

Procedure

A Busch unit was used for the testing with a Sigma motor pump to supply neutralized feed to the unit. (Note Figure 42.) The volume of the aeration chamber in this unit was approximately three liters.

The unit was seeded at two different times with an active domestic seed.

Results and Recommendations

The results of the experiments at retention times of approximately 32 hours and 15 hours have been listed in Table 76. High retention times were chosen because of the inhibition exhibited in the BOD_5 test at various dilutions. The unit was seeded twice but the mixed liquor suspended solids did not build to a level to allow wastage. Feed BOD_5 values were so low (15-42 mg/l) that the system was starving. Solids were carried over at times in the effluent. Microscopic examination of the mixed liquor showed no higher forms of biological growth. Oxygen uptake rates (mg/l/hour) were quite low as would be expected with such a low level of volatile mixed liquor suspended solids. The effluent BOD_5 level from the unit averaged approximately 10 mg/l.

Phenol levels of approximately 6-7 mg/l were recorded for the influent to the biosystem. Effluent levels did not drop below 1 mg/l which is above the effluent criteria of 0.3 mg/l. It is also known that the 4-aminoantpyrine method does not detect various substituted phenols present in the waste.

The average COD removals are listed below:

Avg. Retention Time	% COD Removal	Range	No.of Observations
32 hours	~33	19 - 44	18
15 hours	~32	14 - 42	8

In Table 77 it was noted that COD removals of up to 100 mg/l were observed yet BOD_5 levels were very low with no recorded values over 30 mg/l. This may indicate that some mechanism other than biological degradation could be responsible for the organics reduction. (Note section on aeration experiments.)

A biosystem can function, but there will probably be constant upsets and a very low level of biological activity. During the pilot plant operation another attempt was made to acclimate a domestic sludge to the Sauget waste using a technique described in the next section.

PILOT PLANT ACTIVATED SLUDGE UNIT

On 5/11/71, 10 gallons of secondary underflow were added to the 90 gallon aeration tank and neutralized clarified waste was fed to the system on a batch basis. Approximately 10 gallons was fed to the system daily for 7 days until the tank was full on 5/18 when continuous flow was started. The retention time for the first 35 days of continuous operation varied from 35 to 52 hours (note Table 78). On 5/30/71 a dilute milk solution with a BOD_5 of approximately 2400 mg/l was fed to the biosystem on a continuous basis along with ammonium chloride and sodium dihydrogen phosphate. Solids were not building in the system and it was hoped that adding the additional substrate would aid in maintaining a viable system which could adapt to the Sauget waste. It is questionable whether or not this method of acclimation will aid in adaption of the biota to the waste because they may feed only on the very readily degradable milk and not touch the other organic constituents in the waste.

In Table 78 the effluent BOD_5 values from 5/30 - 6/30 have been listed and range from 66 to 120 mg/l which indicates poor BOD_5 removal for aeration times of from 28 to 58 hours. As mentioned previously, high retention times were chosen because of inhibitory effects. It was planned to drop the retention time if the biomass could be built up, but this was never achieved. Loadings were essentially in the extended aeration range or at the low end of the range for conventional activated sludge. Note calculations below:

Diluted Milk Solution

$BOD_5 \sim 2400$ mg/l

Addition Rate (gm BOD/day)

$$\left(\frac{16\text{ ml}}{\text{min.}}\right)\left(\frac{1440\text{ min}}{\text{day}}\right)\left(\frac{2400\text{ gm}}{10^6\text{ gm}}\right)\left(\frac{1\text{ gm}}{\text{ml}}\right) = 55.4\ \frac{\text{gm } BOD_5}{\text{day}}$$

Waste Flow

150 ml/min.

$BOD_5 \sim 90$ mg/l

$$\frac{(150\ \text{ml})}{(\text{min.})}\ \frac{(1\ \text{gm})}{(\text{ml})}\ \frac{(1440\ \text{min})}{(\text{day})}\ \frac{(90\ \text{gm})}{(10^6\text{gm})} = 19.5\ \frac{\text{gm}}{\text{day}}$$

Approximately three times the BOD_5 was being added by the milk compared with the waste.

$$\frac{75\ \text{gm/day}}{454\ \text{gm/lb}} = \frac{0.165\ \text{lbs}\ BOD_5}{\text{day}}$$

Loading

MLSS $\sim$ 1600 mg/l % Volatiles 60%

VMLSS $\sim$ 960 mg/l $\frac{326\ \text{gm}}{454\ \text{gm}} = 0.72$ lbs VMLSS

$$90\ \text{gal} \times 3.785\ \frac{\text{l}}{\text{gal}} = 340\ \text{l}$$

$$\frac{0.96\ \text{gm}}{\text{l}} \times 340\ \text{l} = 326\ \text{gm} \qquad \frac{\text{lbs}\ BOD_5}{\text{lbs VMLSS}} = \frac{0.165}{0.72} = 0.23$$

$$(90\ \text{gal})\ \frac{(1\ \text{ft}^3)}{(7.48\ \text{gal})} = 12\ \text{ft}^3$$

$$\frac{0.165\ \text{lbs}\ BOD_5}{(0.012)\ 1000\ \text{ft}^3} \cong \frac{14\ \text{lbs}\ BOD_5}{1000\ \text{ft}^3}$$

The organic loading was approximately $\frac{0.23\ \text{lbs}\ BOD_5}{\text{lbs VMLSS}}$ which is on the low end of the range for conventional activated sludge but the volumetric loading was approximately 14 lbs of $BOD_5/1000\ \text{ft}^3$ which would be considered extended aeration. These loadings were considerably higher than those for previous studies during the laboratory phase of the project.

On 6/10 the effluent solids rose to 373 mg/l from a level of 52 mg/l on the previous day and rose again on 6/12 to over 1000 mg/l. The system was seeded on 6/23/71 with domestic underflow because the solids had dropped to well below 1000 mg/l and the oxygen uptake rate was essentially zero. After reseeding, difficulty was experienced in maintaining a low level of solids in the clarifier overflow. The recycle rate was high but the overflow rate was at a low level (100 gal/day - ft^2) so that adequate settling should have occurred.

AERATION EXPERIMENTS

Purpose: (Batch Experiments)

Whenever a waste stream is known to contain volatile organic components, the possibility that a dual mechanism of removal in an activated sludge aeration system is likely. Organic contaminants may be removed either by biological degradation or by air stripping in such a system. Another possibility is direct oxidation of certain compounds.

During early batch treatability studies, a distinct odor was noticeable during the time when draw and fill units were being fed neutralized waste from the Sauget treatment plant.

At that time it was decided that the amount of removal of organics attributable to air stripping must be determined to adequately evaluate the performance of a biological system. The possibility of air oxidation of certain constituents would also be investigated.

Procedure: (Batch Tests)

A graduated cylinder was filled with waste water and the organic level recorded at specified periods of time following the start of aeration.

Results: (Batch Tests)

Batch tests were first run on 11/11/70 and the samples were analyzed using a Beckman Total Carbon Analyzer. The results are inconclusive because of an apparent rise in the organic carbon level in the samples after 18 and 22.5 hours of aeration.

Tests were conducted again on 5/25/71 and 5/16/71 and indicated that aeration eliminated 38% and 21% of the COD in a period of less than 24 hours. (Note Table 79 for data, and Figure 43).

Purpose: (Continuous Experiments)

Because the air rate was not controlled during the batch experiments and waste composition varies, it was necessary to conduct further experiments to determine if the air rate equivalent to that for the activated sludge system would be sufficient to allow a significant COD reduction in the aeration tank with no biomass present.

Procedure: (Continuous Test)

A Busch Unit (Figure 42) was fed continuously with neutralized settled waste and a regulated amount of air was sparged through the system. The same waste was being fed to the pilot plant activated sludge system.

The air rate to the 90-gallon tank was approximately 105 cfh or 1.17 cfh/gal.

The air rate to the Busch unit was then controlled at approximately $\frac{5 \text{ liter}}{3.785 \text{ l/gal}} \times 1.17 \frac{\text{cfh}}{\text{gal}} = 1.56 \text{ cfh}$

A direct comparison cannot be made between COD or BOD_5 removals for the two units because milk was being fed continuously to the 90-gallon aeration chamber as an additional substrate.

A comparison, however, can be made with the previous experiments with the Busch unit and the larger biosystem before the addition of milk.

During the period from 3/2/71 until 4/16/71 a Busch unit was fed neutralized effluent. (Note Table 76 showing data collected during this period.) COD removals ranged from essentially zero to 46% for 34 observations with an average value of 26%. This COD removal was achieved at an average retention time of less than 30 hours with comparable removals also achieved at a retention time of less than 20 hours.

During the period when average BOD_5 removal was less than 30 mg/l comparing the feed and effluent, the COD removals were as high as 100 mg/l.

Table 77 lists the data for the pilot plant system before milk was fed to the system as an additional substrate and COD removals for 6 observations ranged from 30 to 49% with an average value of 41%. The retention time was approximately 48 hours.

During the air stripping experiment the COD removals varied from 39 to 50% at a retention time of 44 hours with an average removal of 44% for 6 observations. (Note Table 80) Table 81 summarizes the results of the various aeration experiments.

Direct Oxidation by Oxygen or Chlorine

Direct oxidation of the organics constituents in the waste did occur on certain occasions when there was a high concentration of free chlorine in the waste. It is possible that some of the COD reduction could be attributed to a reaction of certain constituents with chlorine but this is not very likely because of the concentrations of free chlorine we observed in the feed. Table 82 lists the free chlorine values in the chemical effluent during a portion of the period we are concerned with for the aeration experiments.

Any free chlorine would have reacted with waste constituents while retained in the sewer, pump station and pilot plant (grit chamber, neutralization basin or clarifier). Total retention time was ~5 hours.

It appears unlikely that oxygen would readily react with any of the organic constituents; however, it would readily oxidize sulfite. Monsanto manufactures sodium sulfite and the loss to the sewer would be approximately 7.4 lbs/min sulfite, if discharged over the entire day. In 17,000 gpm this would correspond to 52 ppm or 18.6 ppm of COD. Because sulfite is such a rapid scavenger of oxygen, the sulfite would undoubtedly be oxidized rather rapidly. Abnormal dumps could possibly have sulfite present after the chemical system.

Figure 27

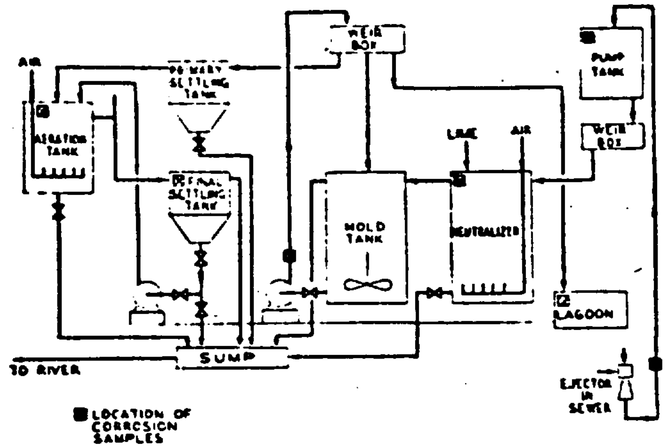


Figure 5—Flow diagram of waste treatment pilot plant.

Table 67

TABLE 1—Composition of Combined Monsanto Village Sewage Before and After Activated Sludge Treatment

Property	Typical Data of 24-hour Composite Sample Removed From Main Sewer	Typical Data of Effluent Sample Removed After Final Settling Tank
pH	8.0	7.9
Settleable Solids	2.5 mg/L	0.9 mg L
Suspended Solids	150 ppm	112 ppm
Dissolved Solids	2500 ppm	2500 ppm
Chlorides	600 ppm	600 ppm
Total Acid	300 ppm	....
COD	700 ppm	221 ppm
BOD	300 ppm	90 ppm
Phenol	50 ppm	4 ppm
Oil	25 ppm	4 ppm
Threshold Odor No.	300	20
Flow	36×10^6 gal/day; 2-3 ft/sec.	30 gal/min; 5.2 ft/sec.

TABLE 67
COMPARISON OF 1959 & 1971 WASTE STREAMS
FROM THE VILLAGE OF SAUGET

	1959	1971
Village of Sauget		
Flow	36 MGD	24 MGD
BOD_5	300 mg/l	75 mg/l
	88,700 lbs/day	15,000 lbs/
Phenol	50 mg/l	<5 mg/l
	14,700 lbs/day	1000 lbs/da
BOD_5 (Phenol)*	~120 mg/l	<12 mg/l
	35,000 lbs/day	2400 lbs/da
Individual Contributors		
Monsanto		
Flow	25 MGD	14 MGD
Phenol	9700 lbs/day	<1000 lbs/da
BOD (Phenol)*	23,000 lbs/day	<2400 lbs/da
Mobil Oil		
Flow	1.5 MGD	0
Phenol	40 mg/l	--
	500 lbs/day	--
BOD_5	225 mg/l	--
	2800 lbs/day	--

*Assume all of phenol is degradable 2.38 gm BOD_5/gm Phenol

Monsanto

QUALITY CONTROL

FREQUENCY DISTRIBUTION ANALYSIS SHEET

DEPT | CODE | PRODUCT RAW WASTE BOD | TEST OF Village of Sauget Effluent | DATE 1/14/72

PLANT | UPPER SPECIFICATION LIMIT | LOWER SPECIFICATION LIMIT | PERIOD COVERED 3/10/71 - 7/1/71 | Dilution % - 2 or Less | DATA ANALYZED BY

% UNDER SPEC | % OVER SPEC | DISTRIBUTION TYPE

CONTROL LIMIT SCALES (3σ)

1 X	TALLY	2 f	5 Acc. 2	6 5 ÷ 4 in % over
200+	6	6	6	2.6
180-200	3	3	15	6.4
160-180	5	5.	23	9.8
140-160	9	9	37	15.8
120-140	11	11	57	24.4
100-120	21	21	89	38
80-100	22	22	132	56.5
60-80	15	15	169	72
40-60	11	11	195	83.4
20-40	7	7	213	91
0-20	7	7	227	97

3 TOTAL 117

4 DOUBLE TOTAL 234

UCL | LCL | PROC CAPABILITY

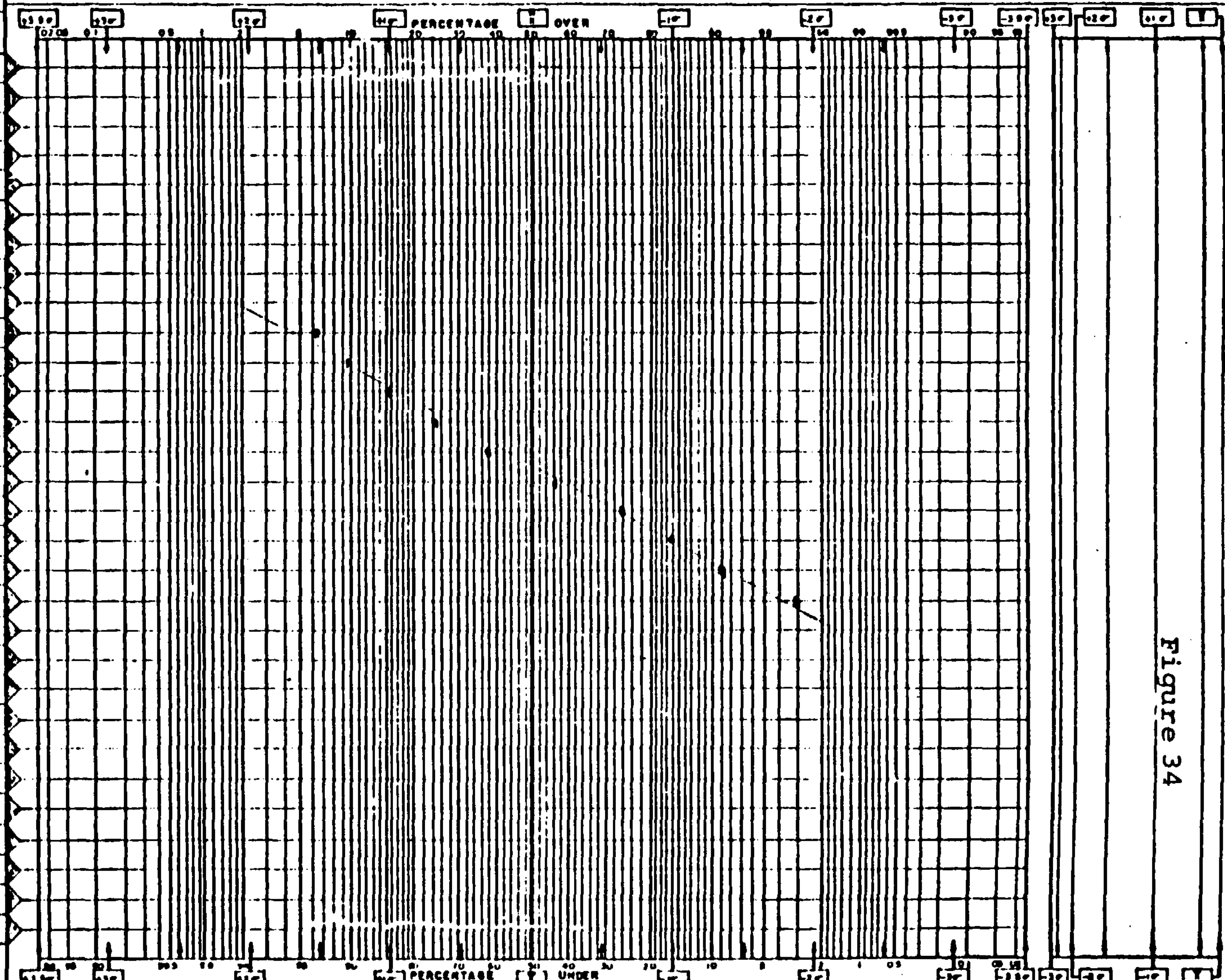


Figure 34

QUALITY CONTROL
FREQUENCY DISTRIBUTION ANALYSIS SHEET

DEPT		TEST	DATE
	Dilution 4% or Lower	Chemical Effluent BOD5	1/14/71
PLANT	UPPER SPECIFICATION LIMIT / LOWER SPECIFICATION LIMIT	PERIOD COVERED: 5/30 TO 7/21/71 — IN mg/l	DATA ANALYZED BY: W.J.F.

% UNDER SPEC | % OVER SPEC | DISTRIBUTION TYPE | σ (FOR CC)

1 X	TALLY	2 f	5 Acc. 2	6 5 ÷ 4 IN % OVER
220	1	1	1	0.5
200	3	3	5	2.7
180	0	0	8	4.3
160	4	4	12	6.5
140	2	2	18	10
120	3	3	23	13
100	19	19	45	24
80	25	25	81	48
60	19	19	133	72
40	12	12	164	81
20	4	4	180	97.8
0	0	–		

$UCL_{\bar{X}}$	UCL_{X}	3 TOTAL	92	UCL_R
$LCL_{\bar{X}}$	LCL_{X}	4 DOUBLE TOTAL	184	LCL_R
PROC. CAPABILITY	$\bar{x}$: 30 mg/l	σ: 90 mg/l		

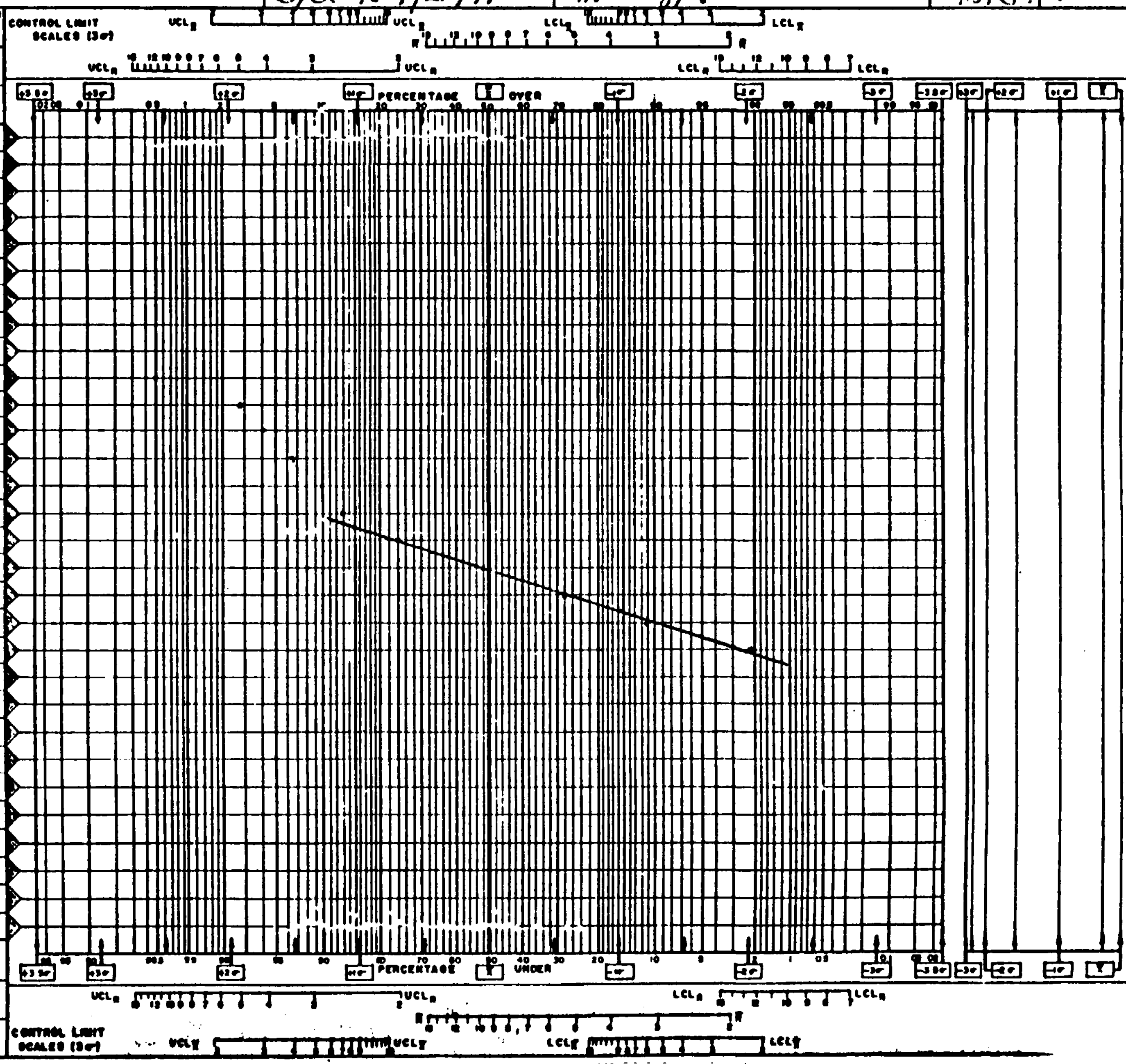


TABLE 68
VILLAGE WASTE
CHLORINE CONCENTRATIONS

Date		Free Cl_2	Total
3/11/71	Chlorine Dump *Raw	>>1	>>1
3/23	Chemical Effluent		<0.01
3/29	Chemical Effluent	<0.01	<0.01
5/12	Raw Influent	<0.01	<0.01
5/12	Chemical Effluent	<0.01	<0.01
7/20	Raw Influent	0.51	3.1
6/12	Chemical Effluent	<0.01	<0.01
6/13	Chemical Effluent	<0.01	<0.01
6/18	Chemical Effluent	<0.01	<0.01
5/12	Chemical Effluent	<0.01	<0.01
5/13	Chemical Effluent	<0.01	<0.01
5/14	Chemical Effluent	<0.01	<0.01
5/15	Chemical Effluent	<0.01	<0.01
5/16	Chemical Effluent	<0.01	<0.01
5/17	Chemical Effluent	<0.01	<0.01
5/18	Chemical Effluent	<0.01	<0.01
5/19	Chemical Effluent	<0.01	<0.01
5/21	Chemical Effluent	<0.01	<0.01
5/22	Chemical Effluent	<0.01	<0.01
6/1	Chemical Effluent	<0.01	<0.01

* Personnel required to leave treatment plant because of fumes

** Measurement by Black-Whittle Method for free and total chlorine

TABLE 68 (Continued)
VILLAGE WASTE
CHLORINE CONCENTRATIONS

Raw Waste	Free	Total
5/12/71	<0.01	<0.01
5/13	<0.01	<0.01
5/14	<0.01	<0.01
5/15	<0.01	<0.01
5/16	<0.01	<0.01
5/17	<0.01	<0.01
5/18	<0.01	<0.01
5/19	<0.11	<0.69
5/21	<0.01	<0.01
5/22	<0.01	<0.01
5/23	<0.01	<0.01
5/24	<0.01	<0.01
6/1	<0.01	<0.01
10/18/71		
11:14AM	0.22	
11:22AM	0.02	
11:26AM	16.00	
11:35AM	30.00	
11:45AM	*	

*Sample could not be taken because of the toxic fume hazard.

Table 70

BATCH UNIT ACCLIMATION DATA
UNIT II

Date	Temp. (M.L.)	pH (M.L.)	Feed ml	M.L. T=24 S.S. (mg/l)	T=24 ½ Hr. Sett. (mg/l)	O_2 Uptake mg/l-hr.
10/23/70	-	-	225	-	-	-
24	-	-	325	-	-	-
25	-	-	0	-	-	-
26	-	-	425	-	-	-
27	-	-	525	-	-	-
28	-	-	670	1780	-	-
29	-	-	-	-	-	-
30	-	-	-	540	-	-
31	-	-	-	1640	280	4.2
11/1	75	7.0	-	1710	380	-
2	-	-	670	-	410	-
3	-	-	670	1900	410	-
4	67	-	670	2240	380	-
5	79	7.3	670	-	380	-
6	76	7.0	670	2130	390	-
7	77	6.9	670	-	410	-
8	75	7.1	1400	3230	380	-
9	76	7.0	1400	1940	340	-
10	75	-	-	1790	320	-
11	75	7.6	-	1620	400	-

Table 71

BATCH UNIT ACCLIMATION DATA
UNIT III

Date	Temp. (M.L.)	pH (M.L.)	Feed ml	M.L. T=24 S.S. (mg/l)	T=24 ½ Hr. Sett. (mg/l)
10/23/70	-	-	225	-	-
24	-	-	325	-	-
25	-	-	0	-	-
26	-	-	425	-	-
27	-	-	525	-	-
28	-	-	670	1780	-
29	-	-	-	-	-
30	-	-	-	-	-
31	-	-	-	1440	240
11/1	75	7.0	-	1610	380
2	-	-	670	-	400
3	-	-	670	1830	400
4	67	-	670	2110	385
5	-	7.6	670	-	390
6	74	7.2	670	2180	400
7	76	7.0	670	2010	390
8	74	7.1	1400	2167	460
9	76	7.1	1400	-	400
10	75	-	-	1410	410
11	75	7.5	-	2060	420

Table 72

BATCH UNIT ACCLIMATION DATA
UNIT V

Date	Temp (M.L.)	pH (M.L.)	Feed ml	% Vol.	M.L. T=24 S.S. (mg/l)	T=O TOC (mg/l)	T=24 TOC (mg/l)	T=O I.C. (mg/l)	T=24 I.C. (mg/l)	T=O ½ Hr. Sett. (mg/l)	T=24 ½ Hr. Sett. (mg/l)	pH T=24 (M.L.)
11/22/70	-	6.9	500	-	-	57		26		315	365	6.9
23	71	7.1	500	-	-	-	T=21 41	-	T=12 13	350	430	7.1
24	75	7.5	500	-	-	77	-	41	-	390	390	7.7
25	76	7.3	500	-	-	74	67	42	37	390	320	7.7
26	78	-	-	-	-	70	71	34	39	340	320	7.5
27	76	7.1	-	-	-	70	71	36	33	320	320	7.9
28	73	7.3	-	-	-	64	68	30	31	350	355	7.6
29	76	7.2	-	-	-	68	63	31	28	330	340	7.7
30	71	7.1	500	70.6	3870	66	60	28	25	360	320	7.3
12/1	78	7.2	500	68.7	3490	62	58	28	23	310	360	7.7
2	67	7.2	500	66.3	3510	60	56	27	25	350	330	7.5
3	75	7.0	500	67.6	3230	54	51	24	22	300	260	7.8
4	76	7.1	1000	65.4	3180	53	48	23	20	260	260	7.8
5	72	7.4	1000	74.1	1740	60	44	24	17	250	230	-
6	74	7.1	1000	70.0	1460	61	48	24	18	260	240	-
7	76	7.3	1000	-	1540	59	53	24	21	290	-	7.7
8	-	-	-	-	-	-	-	-	-	-	240	-
9	84	7.2	1000	64.0	1651	-	-	-	-	280	280	7.6 T=48
10	72	-	800	67.5	1430	-	-	-	-	-	-	-
11	-	-	750	72.3	1690	50	-	19	-	-	-	-
12	72	-	800	57.7	1560	-	-	-	-	280	240	7.6
13	72	7.3	800	42.8	-	-	-	-	-	220	230	7.6
14	72	7.1	800	57.2	1560	-	-	-	-	215	200	7.4

TABLE 73

BATCH TREATABILITY DATA

NEUTRALIZED UNSETTLED PRIMARY PLANT EFFLUENT

UNIT II
DATE: 11/11

(Neutralizing Agent - Caustic)

Feed	Time	MLSS (mg/l)	% Volat.	½ Hr. Sett. Test (ml/100 ml)	O_2 Uptake (mg/l-hr)	COD (mg/l)	BOD_5 (mg/l)	TOC (mg/l)	IC (mg/l)	CC (mg/l)	Temp	pH
	0	1,620		18		119	52	44	17	27		7.8
	½	1,660		15		97	67	41	16	25		7.8
	1	1,710		18		97	65	39	14	25		7.3
	1½	1,710		14		97	54	40	13	27		7.4
	4	1,710		15		177	43	36	10	26		7.3
	7	1,670		15	3 mg/1 hr.	155	23	34	8	26		7.5
	23	1,760		16		123	13	28	6	22		7.5
	30	1,900		16	1.8 mg/1 hr.	139	15	29	5	24		7.7
	48	1,950		15		108	20	30	6	24		6.3

TABLE 74

BATCH TREATABILITY DATA

NEUTRALIZED SETTLED PRIMARY PLANT EFFLUENT

UNIT III
DATE: 11/11

(Neutralizing Agent.- Caustic)

Feed	Time	MLSS (mg/l)	% Volat.	½Hr. Sett. Test (ml/100 ml)	O_2 Uptake (mg/l-hr)	COD (mg/l)	BOD_5 (mg/l)	TOC (mg/l)	IC (mg/l)	OC (mg/l)	Temp °F	pH
	0	2,060		13		209	73	46	14	32		7.6
	½	1,900		18		418	63	43	13	30		7.6
	1	2,020		17		188	68	43	12	31		7.5
	1½	1,880		17		193	59	40	11	29		7.5
	4	2,020		17		177	54	38	9	29		7.5
	7	1,960		17	3.3mg/l hr.	166	22	35	8	27		7.6
	23	2,080		18		145	13	30	6	24		7.7
	30	1,960		18	2.5	144	13	30	5	25		7.8
	48	2,190		18		116	13	29	6	23		6.7

TABLE 75

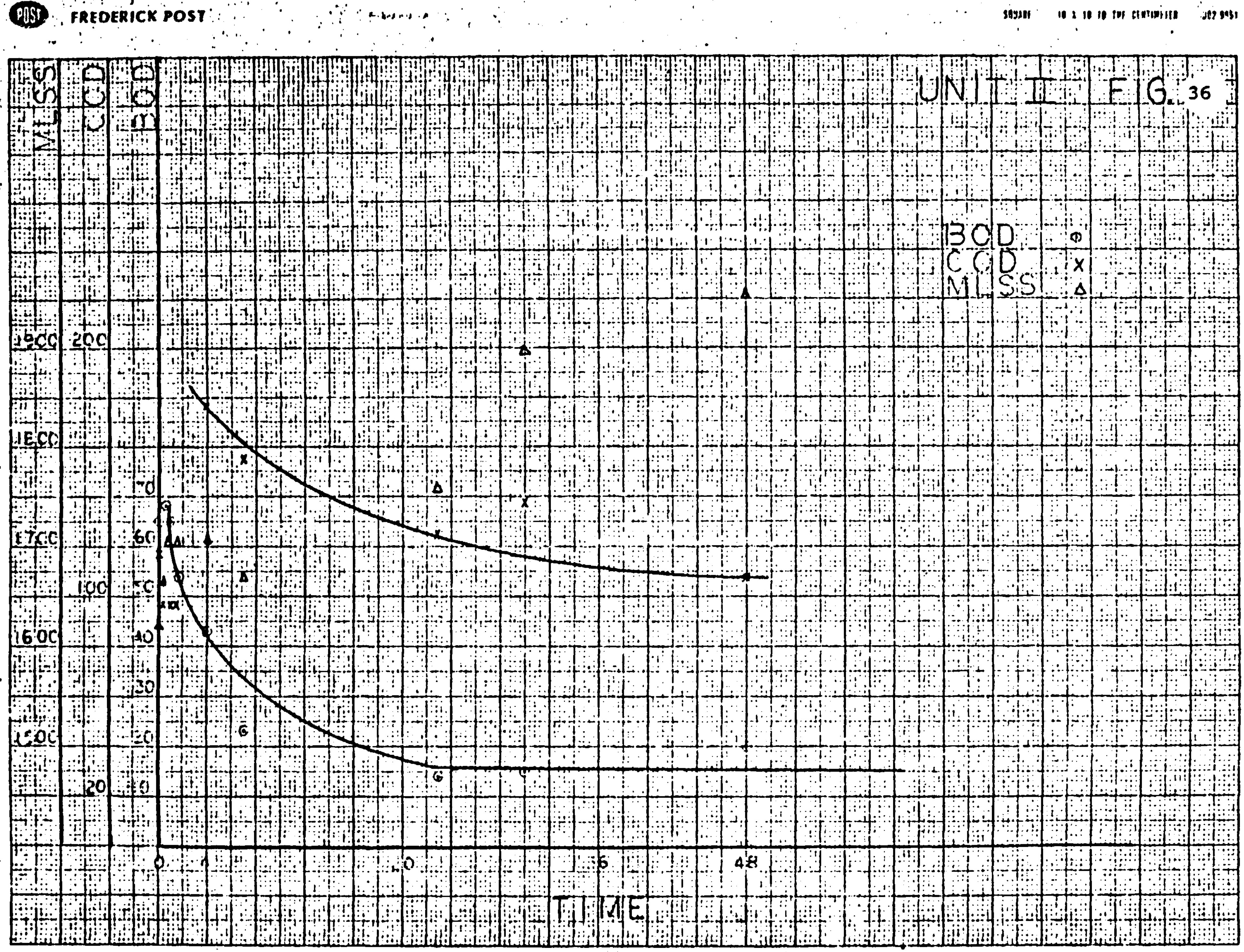
BATCH TREATABILITY DATA

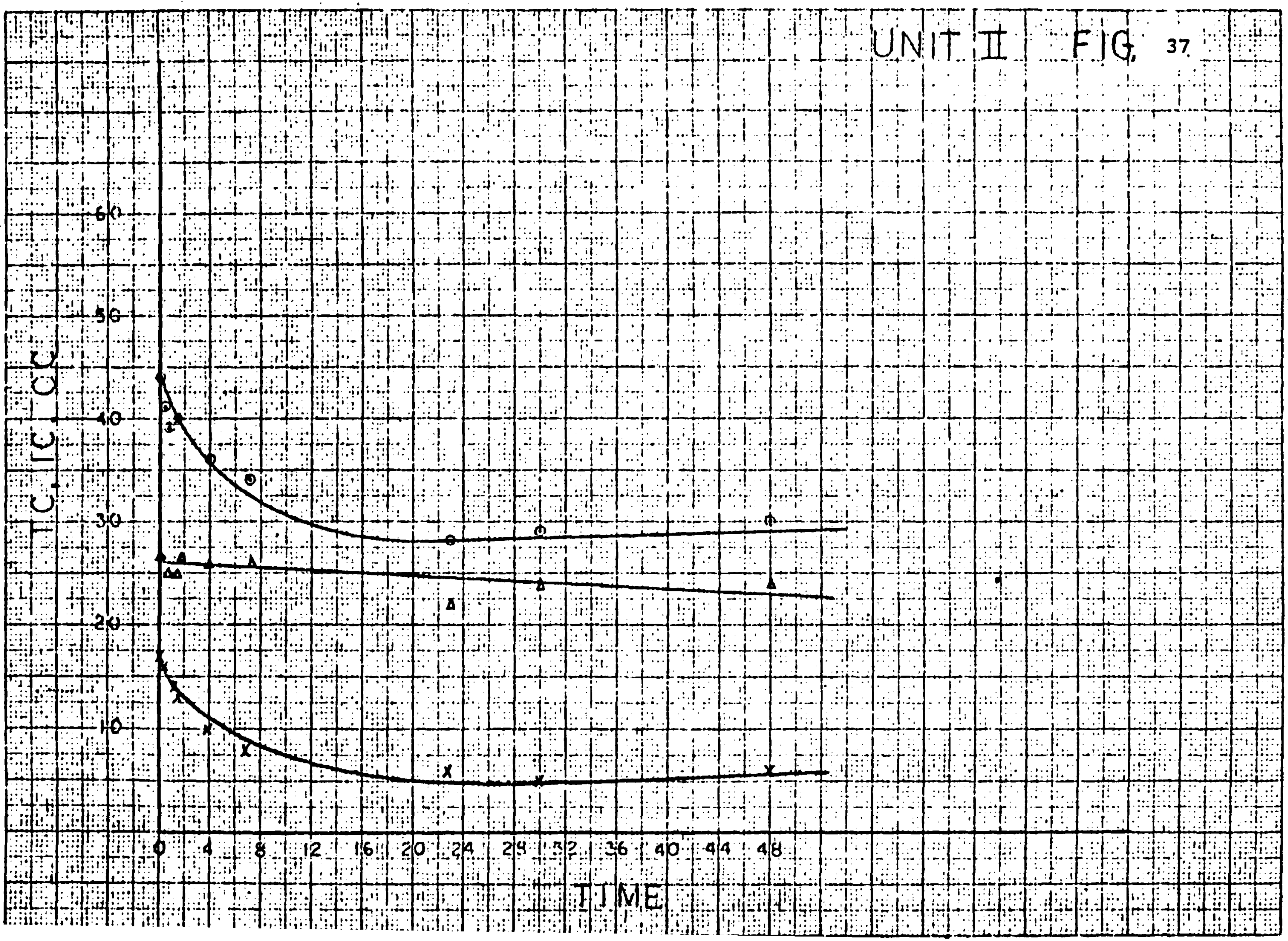
NEUTRALIZED SETTLED PLANT EFFLUENT

(Neutralizing Agent - Lime)

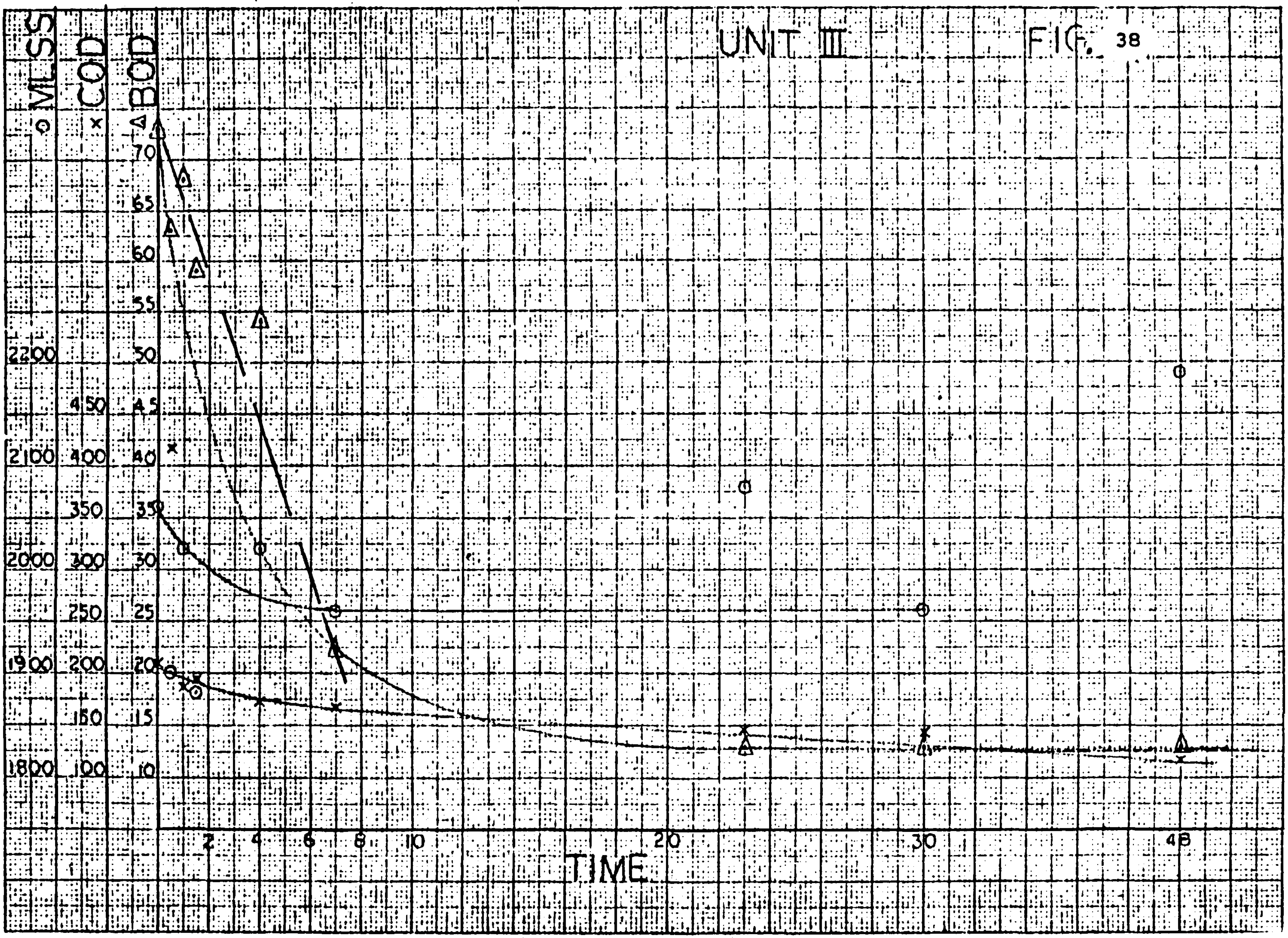
UNIT V
DATE: 12/15/70

Feed	Time	MLSS (mg/l)	% Volat.	½Hr. Sett. Test (ml/100 ml)	O_2 Uptake (mg/l-hr)	COD (mg/l)	BOD_5 (mg/l)	TOC (mg/l)	IC (mg/l)	OC (mg/l)	Temp °F	pH
	0	1,310	66.4	8	4.8	312	71	66	32	34		7.0
	½	1,335	60.9	8	4.2	265	69	63	32	31		6.7
	1	1,370	68.2	8	4.8	371	73	63	30	33		6.8
	2½	1,360	69.0	7	6.6	556	63	57	30	27		7.1
	4	1,340	63.6	7	7.2	521	52	56	30	26		7.1
	6	1,385	69.9	7	6.0	445	21	54	30	24		7.4
	8½	1,230	64.1	-	6.0	427	20	48	25	23		7.5
	22	1,370	64.2	7	4.2	451	6	44	21	23		7.8
	26½	1,370	58.7	7	3.6	80	13	44	23	21		7.5
	30	1,485	58.9	6	3.6	124	23	50	28	22		7.4
	48	1,580	55.3	6	1.8	174	27	45	22	23		7.3

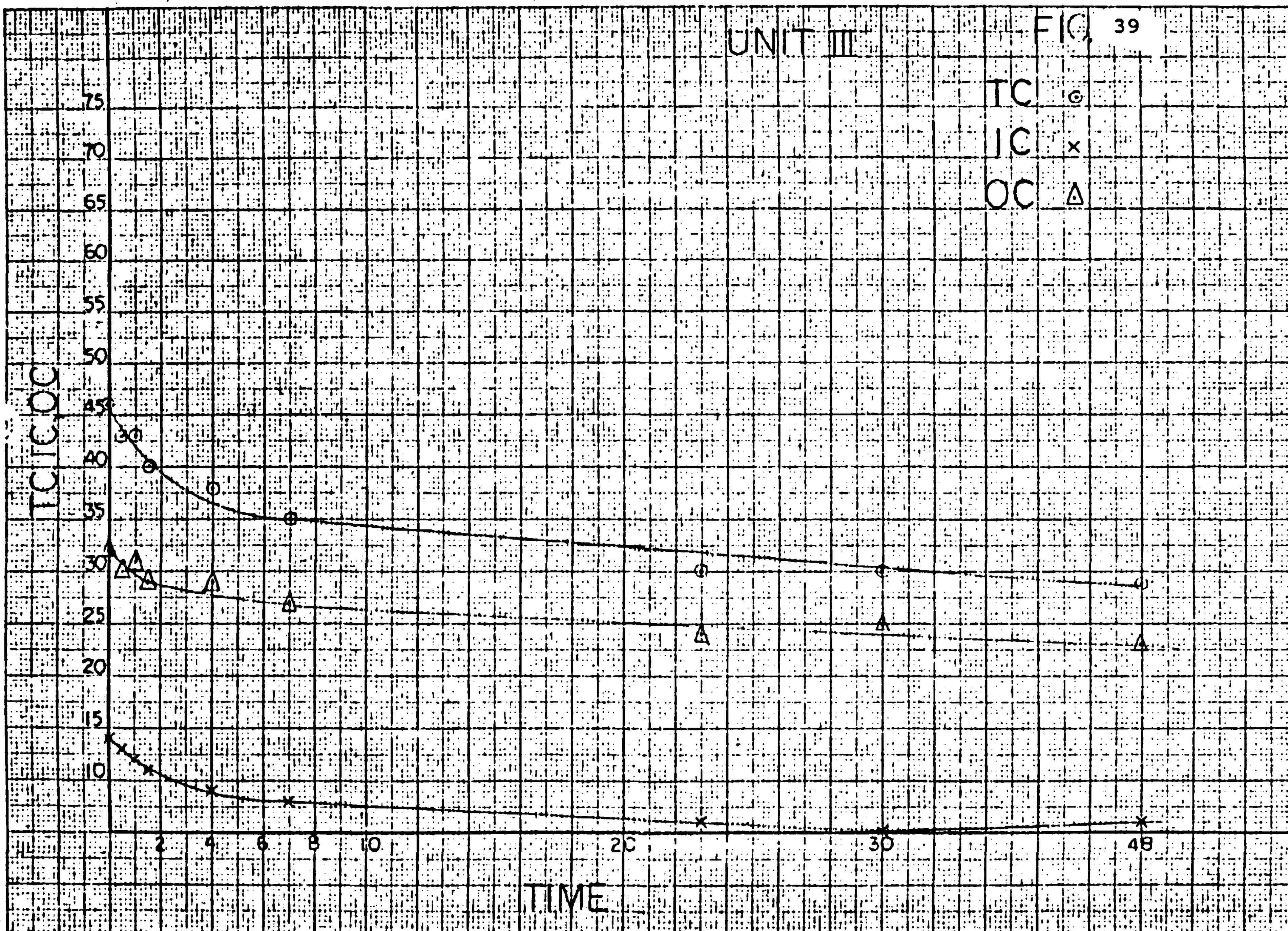

FREDERICK POST
UNIT II FIG. 36
BOD
COD
MLSS
TIME
MLSS
COD
BOD
48



UNIT II FIG. 37


UNIT III
FIG. 38
MLSS
COD
BOD
2200
2100
2000
1900
1800
450
400
350
300
250
200
150
100
70
65
60
55
50
45
40
35
30
25
20
15
10
2
4
6
8
10
20
30
48
TIME

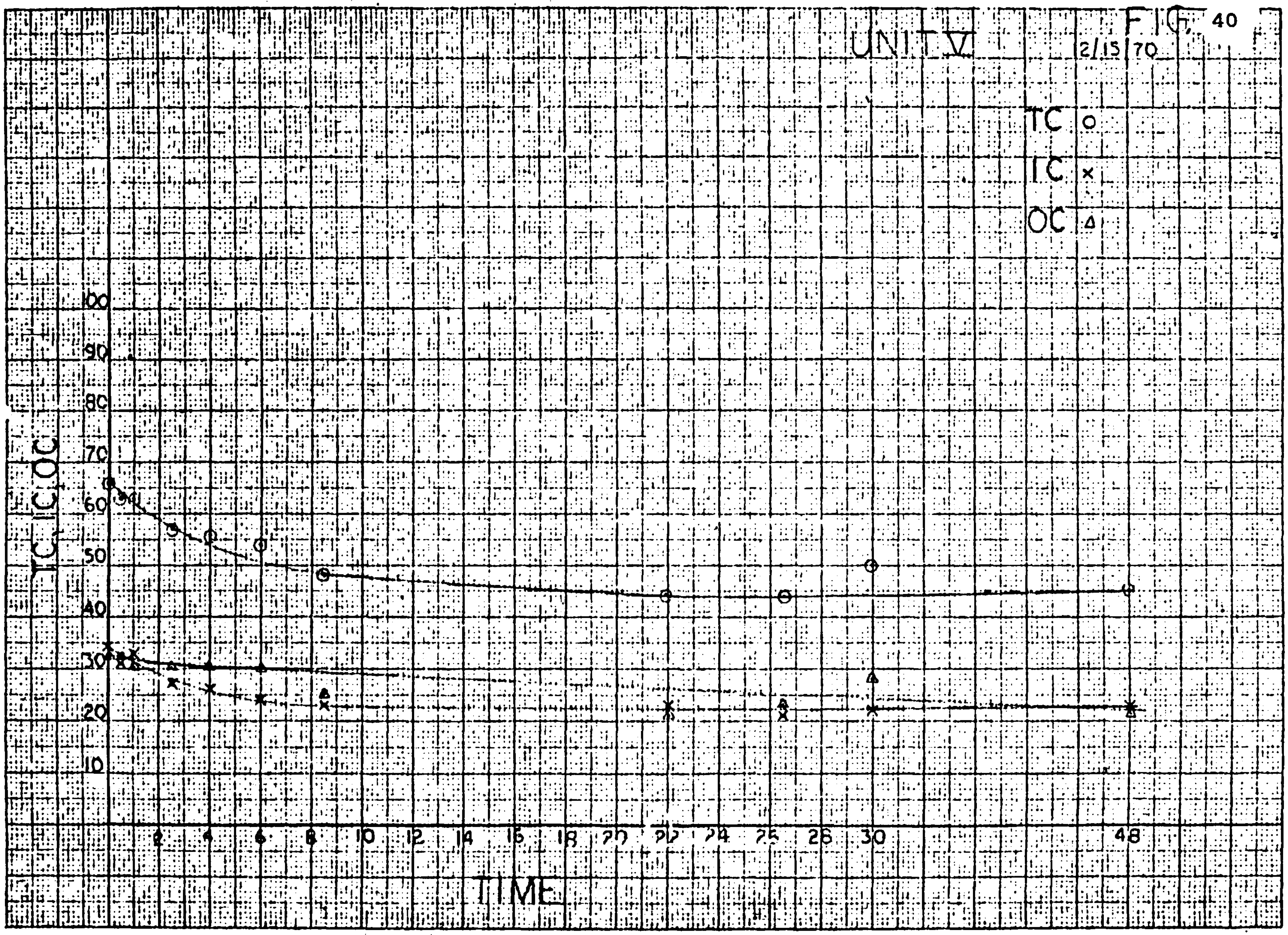
FREDERICK POST



APPENDIX X & XI

Carbon Treatment
and Regeneration Data

FREDERICK POST



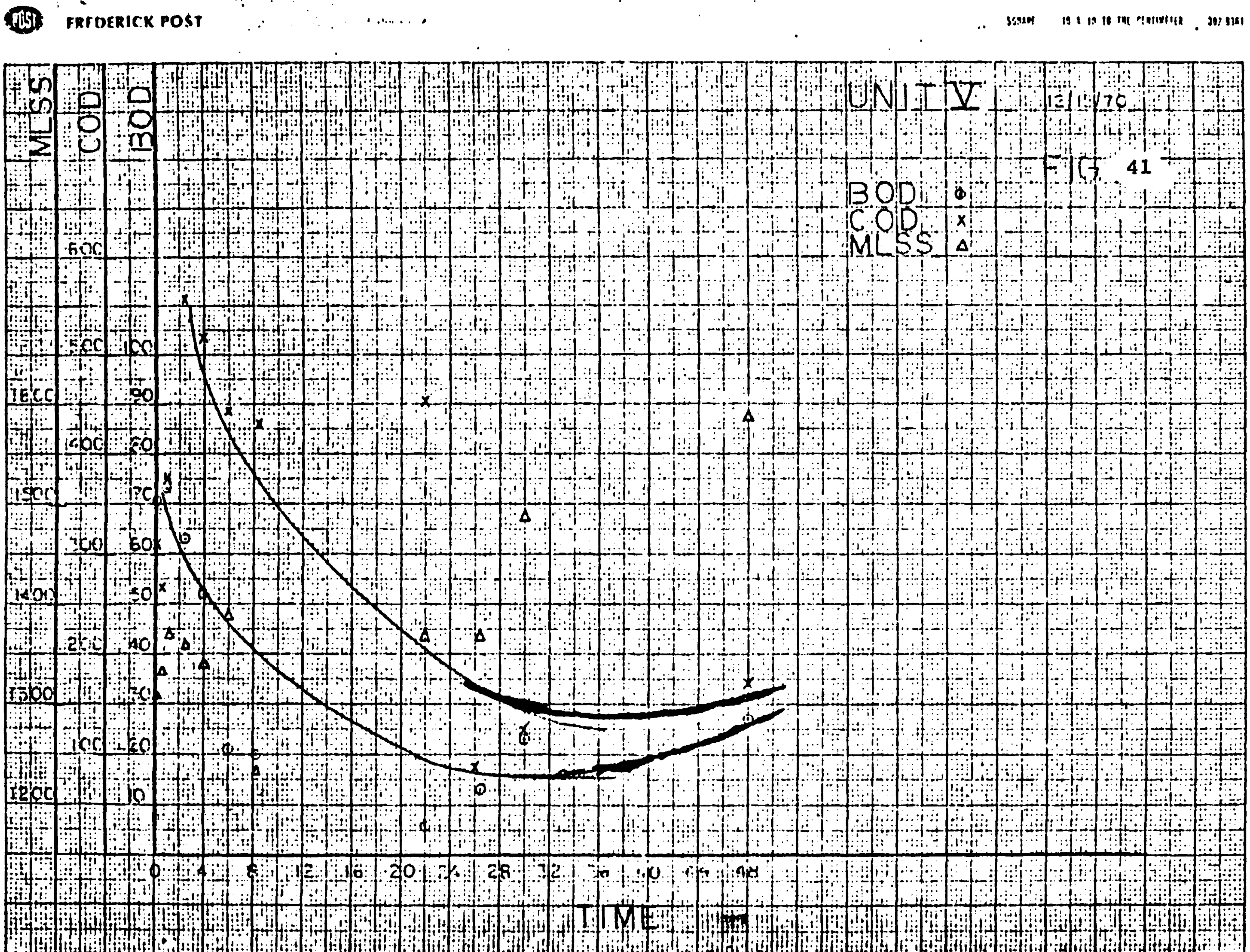
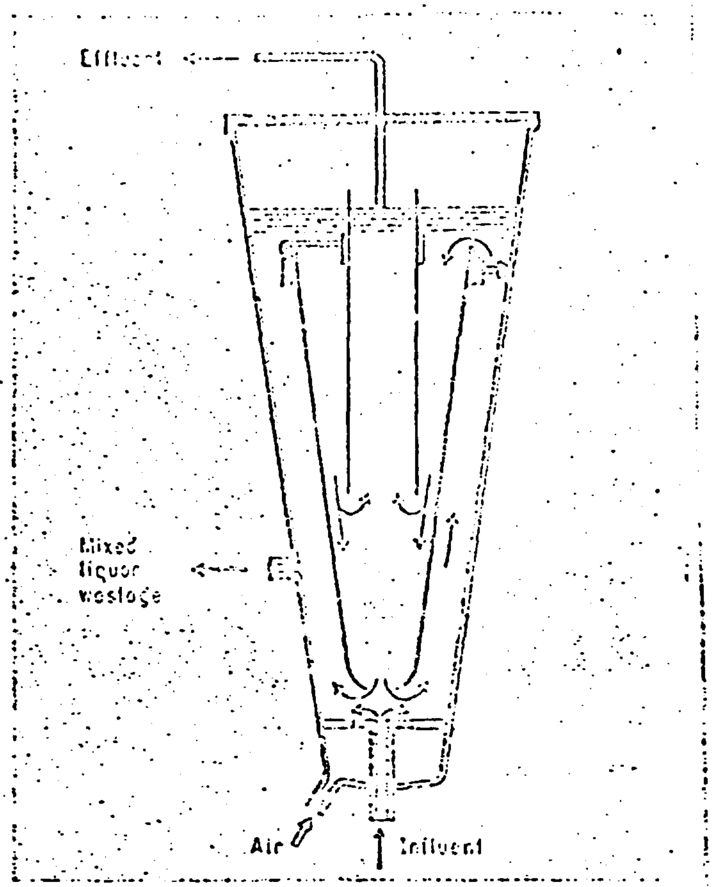

FREDERICK POST
UNIT V
MLSS
COD
BOD
BOD ⊕
COD x
MLSS Δ
TIME
0 4 8 12 16 20 24 28 32 36 40 44 48

FIG. 41

FIGURE 42

BUSCH UNIT



Continuous-flow device for obtaining design data for plants that use bio-oxidation or wastes—Fig. 1

TABLE 76

CONTINUOUS BIOLOGICAL TREATMENT DATA

Date	pH	Retention Time (Hr)	Settling Test (mg/l)	O_2 Uptake (mg/l/hr)	MLSS (mg/l)	% Vol.	BOD (mg/l) Feed	BOD (mg/l) Eff	PHENOL (mg/l) Feed	PHENOL (mg/l) Eff	COD (mg/l) Feed	COD (mg/l) Eff	% Removal	COPPER (mg/l) Feed	COPPER (mg/l) Eff
3/ 2/71											249	166	33	1.4	<0.1
3		32	140		2,370	81					272	201	26	1.1	
4		21	220		2,990	74			6	1	266	216	19		<0.1
5	7.8	45	130		1,880	69			7			374	-		<0.1
6	7.6	34	130		1.870	73				6	250	297	0	1.2	<0.1
7	7.5	27	120		1,760	71			7		282	208	26	0.6	<0.1
8		27							6	1				0.9	<0.1
9	7.9	28	120		2,000	73			6					0.6	
10			120	5.0	1,690	72			6	1				0.7	<0.1
11											336	181	46		
12			95	2.4	1,830	63					188	212	0		
13	8.2	25	120								259	145	44		
14	8.2	23	80								212	165	22		
16											212	149	30		
18											272	212	22		
19		28									201	146	27		
20	8.3	30	80	2.4							189	125	34		
21		29									196	106	46		

TABLE 76

CONTINUOUS BIOLOGICAL TREATMENT DATA

Date	pH	Retention Time (Hr)	Settling Test (mg/l)	O_2 Uptake (mg/l/hr)	MLSS (mg/l)	% Vol.	BOD (mg/l) Food	BOD (mg/l) Eff	PHENOL (mg/l) Food	PHENOL (mg/l) Eff	COD (mg/l) Food	COD (mg/l) Eff	% Removal	COPPER (mg/l) Food	COPPER (mg/l) Eff
3/22/71	7.5	31	70	1.0			42	10			275	186	32		
23	7.9	29	80	2.1			27	2			210	135	36		
24	7.6		170	2.0	1,574	69	17	10			204	165	19		
25	7.9	30	140	0.9	2,780	70	42	16			246	163	34		
26	7.7	32	120	1.2	2,150	72	37	18			258	179	30		
27	8.1	30	80	1.6	1,720	77	40	32			232	955	0		
28	8.2	30	80	1.2	1,850	62					-	172	-		
29	8.2	36	70	1.2	1,450	71	39	10			224	126	44		
30	8.3	42	80	2.0	2,090	65	40	8			215	142	34		
31	8.3	32	70	2.4	1,970	66	24	14			228	447	0		
4/ 2/71	8.4		50	2.4	290	62	14	3			192	169	12		
3	8.1	17	50	1.8	1,150	54	15	5			204	122	40		
4	8.1	16	50	1.8	970	71	14	2			208	125	40		
5	8.1	15	50	1.6	1,430	23	28	1			193	106	45		
6	8.2	13	50	2.4	960	90	15	5			201	166	17		
7	8.1	19	45	2.0	1,160	75	19	5			198	170	14		
8	8.0	15	45	1.6	1,350	65	32	5			200	136	32		

TABLE 76

CONTINUOUS BIOLOGICAL TREATMENT DATA

Date	pH	Retention Time (Hr)	Settling Test (mg/l)	O_2 Uptake (mg/l/hr)	MLSS (mg/l)	% Vol.	BOD (mg/l) Feed	BOD (mg/l) Eff	PHENOL (mg/l) Feed	PHENOL (mg/l) Eff	COD (mg/l) Feed	COD (mg/l) Eff	% Removal	COPPER (mg/l) Feed	COPPER (mg/l) Eff
4/12/71	8.1	9	45	1.6							240	140	42		
13	8.1	23	45	1.2							204	160	22		
14	8.1		40	4.0							116	140	0		
16	8.1		20	4.8							166	183	0		

Table 78

MASTER DATA TABLE

ACTIVATED SLUDGE SYSTEM

Day No.	Date	pH	Temperature	Dissolved Oxygen	1/2 Hr. Settling Test	Suspended Solids	% Volatiles	Sludge Volume Index	Oxygen Uptake (mg/l-hr)	Retention Time (Hr)	Feed Flow ml/min.	Recycle Flow Rate ml/min	Recycle Sludge Suspended Solids	Waste Sludge Volume	Milk Flow ml/min.	% BOD_5 Removal	% COD Removal	% TOC Removal	% Phenol Removal	% Oil Removal	Air Flow (SCFH)	lbs. BOD/day	lbs. BOD/day-1000 ft.^{3}	lbs. BOD/lb. VMLSS	lbs Solids Gen/lbs. BOD
1	5/18									112	118														
2	5/19	7.6	67	3.8	150				5.0	45	126	60													
* 3	5/20	8.0	69		140	1270	62	110		44	130	62													
4	5/21	8.0	69	6.7	190	1020	61	171	4.4	46	124	62													
5	5/22	8.0	68	8.9	150	370	62	—	2.2	47	120	59													
6	5/23	7.9	67	8.4	140	1120	55	[illegible]	3.0	47	116	59													
7	5/24		74	7.5	140			—	7.2	44	130	61													
8	5/25	8.0	69	8.6	140	[illegible]	55	105	3.2	44	130	60													
9	5/26	7.8	68	9.0	145	[illegible]	62	103	4.0	—	0	60													
13	5/30	7.5	73	7.0	[illegible]	[illegible]	56	[illegible]	5.4	44	128	73			7										
14	5/31		74	5.0	145	[illegible]	48	114	6.0	—	0				7										
15	6/1	7.8	74	4.2	140	1270	55	110	7.2	37	154	67			7										
16	6/2	7.5	69	3.7	150	1610	54	93	10.8	44	128	65			7										
17	6/4	7.7	74	6.9	140	[illegible]	64	82	6.6	44	130	66			7						1.7				
18	6/5	7.6	79	5.4	150	1240	57	82	15.6	41	138	68			14						1.5				
19	6/6	8.0	79	5.9	145	1590	62	91	9.6	41	130	70			14						1.8				
20	6/7	7.7	81	4.6	160	1220	65	125	7.8	44	130	63			14										
21	6/8	7.8	77	6.7	160	1650	61	95	7.8	50	114	64			14										
22	6/9	7.8	72	5.7	170	1670	69	102	10.2	53	84/112	65			16						1.8				
23	6/10	8.0		7.2	170	1670	54	102	8.4	38	148	—			16										
24	6/11	7.7	71	7.6	95	1250	63	76	4.8	—		0/100			16										
25	6/12	7.2	72	4.0	55	1060	67	52	9.6	35	160	0/132			16						1.8				
26	6/13	7.4	78	4.4	70	700	76	100	14.4	37	152	0/130			16						1.8				
27	6/14	7.3	74	2.3	70	770	70	91	9.6	39	144	122			16										
28	6/15		74	6.3	60	930	52	65	12.0	—		—			16										
29	6/16							—		51	80/142	134/170			16										
30	6/17			7.5	40	1220	53	33	5.4	37	152	76			16										
31	6/18	7.8	74	6.0	30	970	27	31	6.6	42	134	76/170			16										
32	6/19									40	142	220			16										
33	6/20									44	130	310			16										
34	6/21									52	110	212			16										
35	6/22				10					44	130	240			16						1.8				
36	6/23	7.2	74	0	185	2520	70	73	0	28	200	1200			16						2.0				

* Microscopic Examination

5/20 No higher forms observed

6/1 " " "

Table 78

MASTER DATA TABLE

ACTIVATED SLUDGE SYSTEM

Day No.	Date	pH	Temperature	Dissolved Oxygen	½ Hr. Settling Test	Suspended Solids	% Volatiles	Sludge Volume Index	Oxygen Uptake (mg/1-hr)	Retention Time (Hr)	Feed Flow	Recycle Flow Rate ml/min.	Recycle Sludge	Suspended Solids	Waste Sludge Volume	Milk Flow ml/min	% BOD_5 Removal	% COD Removal	% TOC Removal	% Phenol Removal	% Oil Removal	Air Flow (SCFH)	lbs. BOD/day	lbs. BOD/day-1000 $ft.^3$	lbs. BOD/lb VMLSS	lbs Solids Gen/lbs. BOD
37	6/24	7.4	74	1.5	150	2140	71	71	15	27	192	960				16						1.5				
38	6/25	7.3	77	0.2	190	2200	62	57		30	190	920				20										
39	6/26	7.5	79	4.8	150	1040	64	71	9.6	30	163	960				18						2.0				
40	6/27	7.5	79	5.6	120	1700	70	72	6.9	34	168	720				18						2.0				
41	6/27	7.4	79	5.0	150				10.2	34	168	760				14						2.0				
42	6/[illegible]		79			2000	68			—						14										
43	6/30	7.9	77	7.2	[illegible]	1460	69	69	1.8	34	168	740				10										
44	7/1	7.8	78			1000	11		7.8	—						10										
45	7/2			3.7	80	750	67	107	6.0	32	176	700				8						2.0				
46	7/3	7.9	78	6.8	5				4.0	29	194	700				—						1.8				
47	7/4	6.7	72	7.1	100	2270		44	4.0	32	180	640				—						1.8				
48	7/5	10.0	73	2.8	100				0	32	178	600				-						1.5				
49	7/6	10.5	74	2.6	40				0.8	33	190	600				-						1.5				
50	7/7	9.1														-										
51	7/8	7.8										660				-										

Table 78

MASTER DATA TABLE

(BIOSYSTEM EFFLUENT)

Day No.	Date	pH	Temp. (°F)	BOD 5*	COD*	TOC*	Total Solids*	Susp. Solids*	% Volatiles	Dissolv. Solids*	Phenols*	Color (APHA)	Kjeldahl Nitrogen*	Day No.	Date	pH	Temp. (°F)	BOD 5*	COD*	TOC*	Total Solids*	Susp. Solids*	% Volatiles	Dissolv. Solids*	Phenols*	Color (APHA)	Kjeldahl Nitrogen*
28	6/15		72					1220	36					1	5/18												
30	6/17	7.4		120	357									3	5/20	8.0	69		173			52	77				
31	6/18	7.4	73	104	328		4272	760				>500		4	5/21	7.9	69		176		1841	20	50			100	
32	6/19													5	5/22	8.0	68		177			12	88			100	
35	6/22							478	26					6	5/23	7.9	67									500	
38	6/25	7.3	76		597		4326	111	100	4215		>500		7	5/24		75		165								
39	6/26	7.5	78		485							>500		8	5/25	7.9	69		141	12		42	71				
40	6/27	7.4	78	78	352							>500		9	5/26	8.4	70		162	12		20	90				
42	6/29			85					1094	85				13	5/30			49									
43	6/30	7.8	76	100					100	61		450		14	5/31	7.7	74	38	100			46	83				
44	7/1				266		120		120	64		450		15	6/1	7.7	74	53	99			27	70			>500	
45	7/2	7.5	78		498				844	29		>500		16	6/2	7.6	69	77	244			55	49			>500	
46	7/3	7.9	78						1600	29		>500		17	6/4	7.6	73	52	245			62	87			>500	
47	7/4	7.0	70						54			>500		18	6/5	7.7	78	69	220			49	78			>500	
48	7/5	9.1	72									>500		19	6/6	7.7	77	69	234			45	76			>500	
49	7/6	10.3	73		433							>500		20	6/7	7.8	81	62	259		4086	916	28	3170		>500	
50	7/7				409									21	6/8	7.7	76	54	204			29	79			>500	
51	7/8				347									22	6/9	7.8	70	20	224			52	85			>500	
														23	6/10	7.9		78	245			373	18			>500	
														24	6/11	7.8	69		256			35	77			>500	
														25	6/12	7.6	70		311			1364	27			>500	
														26	6/13	7.7	77		225			37	98			>500	
														27	6/14	7.7	72	83	175			12	100			>500	

*Values Reported in mg/l.

Table 79

TOC REMOVAL

Date	Time	TOC	IC	OC	pH
11/11/70	T=0	50	23	27	7.8
	1.33 hr	28	11	17	7.3
	5.5	27	9	18	7.3
11/12/70	18	35	7	28	7.5
	22.5	31	7	24	7.4

Total Organic Carbon Removal (up to 6 hrs.) 30%

Date	Time	COD
5/25/71	0	243
	1 hr.	198
	2	198
	17	156
	24	156
	48	140
	67	158

Total % Removal ~ 38%

Date	Time	COD
5/16/72	0	263
	0.5	226
	1	226
	2	218
	4	206
	6	206
	24	183
	31	197
	48	209

Total % Removal ~ 24%

Table 77

PILOT PLANT ACTIVATED SLUDGE SYSTEM

Date	COD Influent	COD Effluent	% COD Removal
5/20/71	338	173	49
21	303	176	42
22	251	177	30
23	-	-	-
24	322	165	49
25	224	141	37
26	267	162	39

Table 80

AIR STRIPPING EXPERIMENT

Date	C O D (mg/l) Raw Inf.	Chem. Eff.	Air Strp. Eff.	% Rem.	pH	BOD (mg/l)	Air Rate (SCFH)	Flow (ml/min)	Retention Time
6/4/71	1,630	210	-	-	-	-	1.5	-	
5	612	246	263	-	-	45	0.75/1.25	20	4.2
5	-	-	-	-	-	-	1.75	4.5	18.6
6	408	222	258	-	-	44	1.25/1.5	-	-
7	405	257	128	50	-	21	2/1.75	8.3/5.0	12.6
8	410	264	159	40	-	30	1.6 /1.75	8.3/5.0	12.6
9	347	246	197	20	-	14	1.5	5.0	16.8
24	715	332	202	39	-	49	1.3	1.9	44hr
25	560	286	158	45	-	13	-	2.0	44hr
26	530	326	-	-	-	-	1.75	-	44hr
27	514	288	-	-	-	-	1.75	-	44hr
29	372	267	157	41	-	15	-	-	44hr
'/1/71	528	350	189	46	-	-	-	-	44hr
3	459	263	157	40	7.2	44	0.75/1.75	-	44hr
4	404	325	164	50	7.3	34	0.75/1.75	-	44hr
5	342	306	167	45	10.5	53	1.0 /1.75	4	21hr
6	354	268	256	4.5	-	68	1.25	1	84hr
7	380	349	259	26	8.6	69	-	1	84hr
8	578	314	207	34	7.5	-	-	1	84hr

Table 81

SUMMARY TABLE

Description	Retention Time	% COD Removal
(Continuous Feed) Busch Unit Bio-mass Present	20-30 hrs.	26%
(Continuous Feed) 90 gal Aeration Tank Bio-mass Present	48 hrs.	41%
Continuous Feed Busch Unit No Bio-mass Present	21 hrs.	39%
Continuous Feed Busch Unit No Bio-mass Present	44 hrs.	44%
Batch Test 1 No Bio-mass Present	48 hrs.	38%
Batch Test 2 No Bio-mass Present	48 hrs.	24%

Table 82

CHEMICAL SYSTEM EFFLUENT

Date	Free Chlorine
5/12	0.01 mg/l
13	0.01
14	0.01
15	0.01
16	0.01
17	0.01
18	0.01
19	0.01
20	-
21	0.01
22	0.01

Figure 28

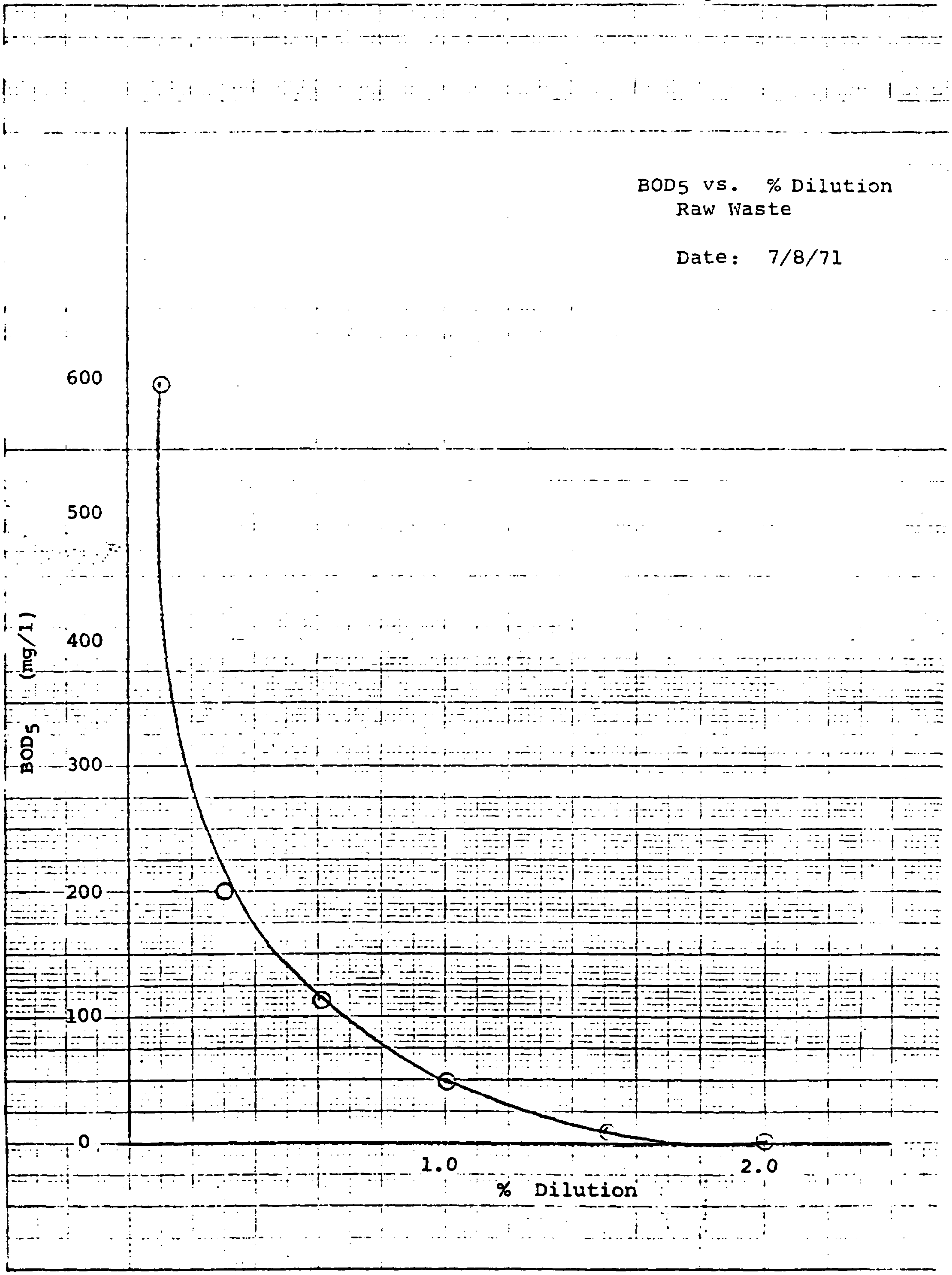
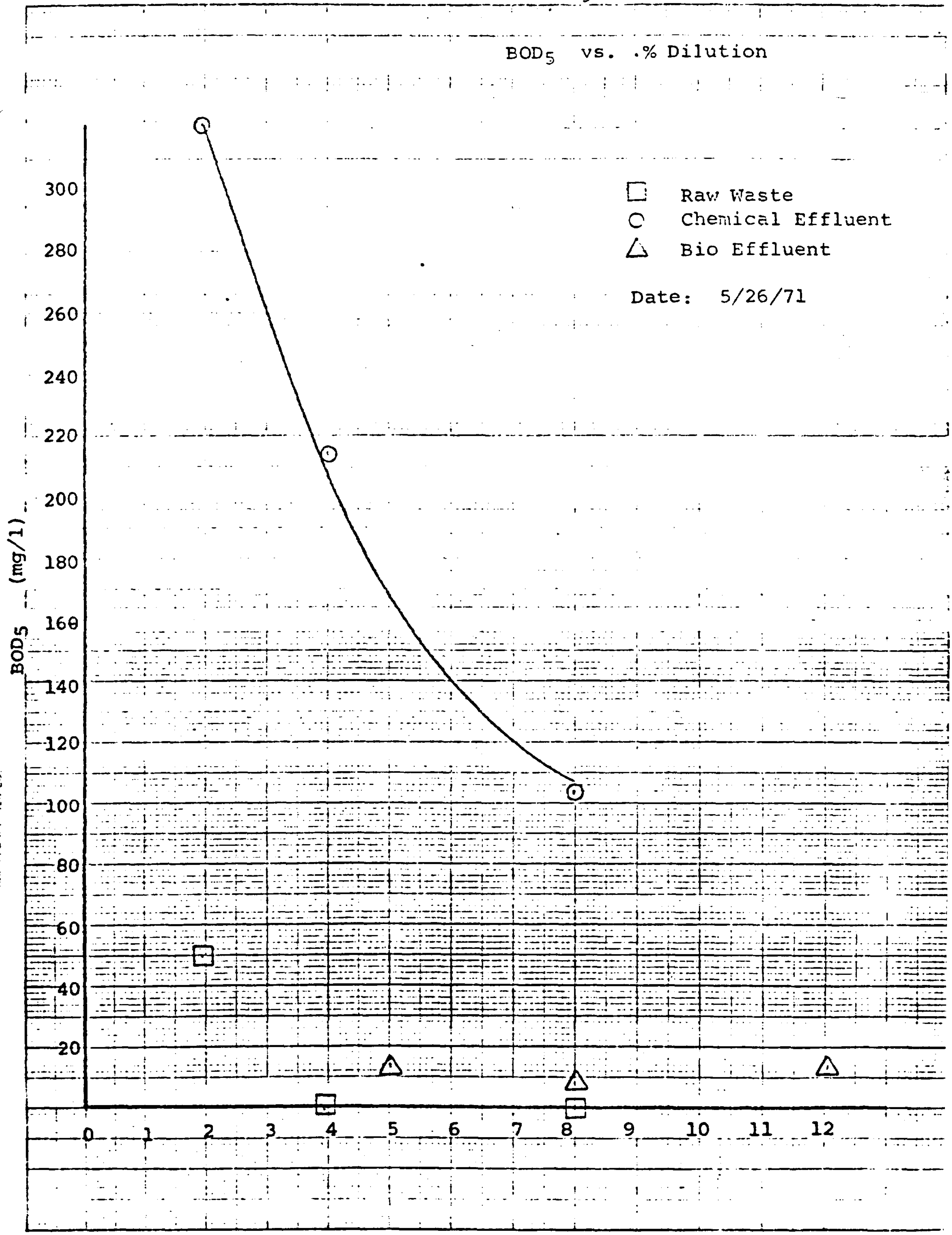

BOD5 vs. % Dilution
Raw Waste
Date: 7/8/71
600
500
400
300
200
100
0
BOD5 (mg/l)
1.0
2.0
% Dilution

Figure 29



BOD5 vs. % Dilution
Raw Waste
Chemical Effluent
Bio Effluent
Date: 5/26/71
BOD5 (mg/1)
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
1
2
3
4
5
6
7
8
9
10
11
12

Figure 30

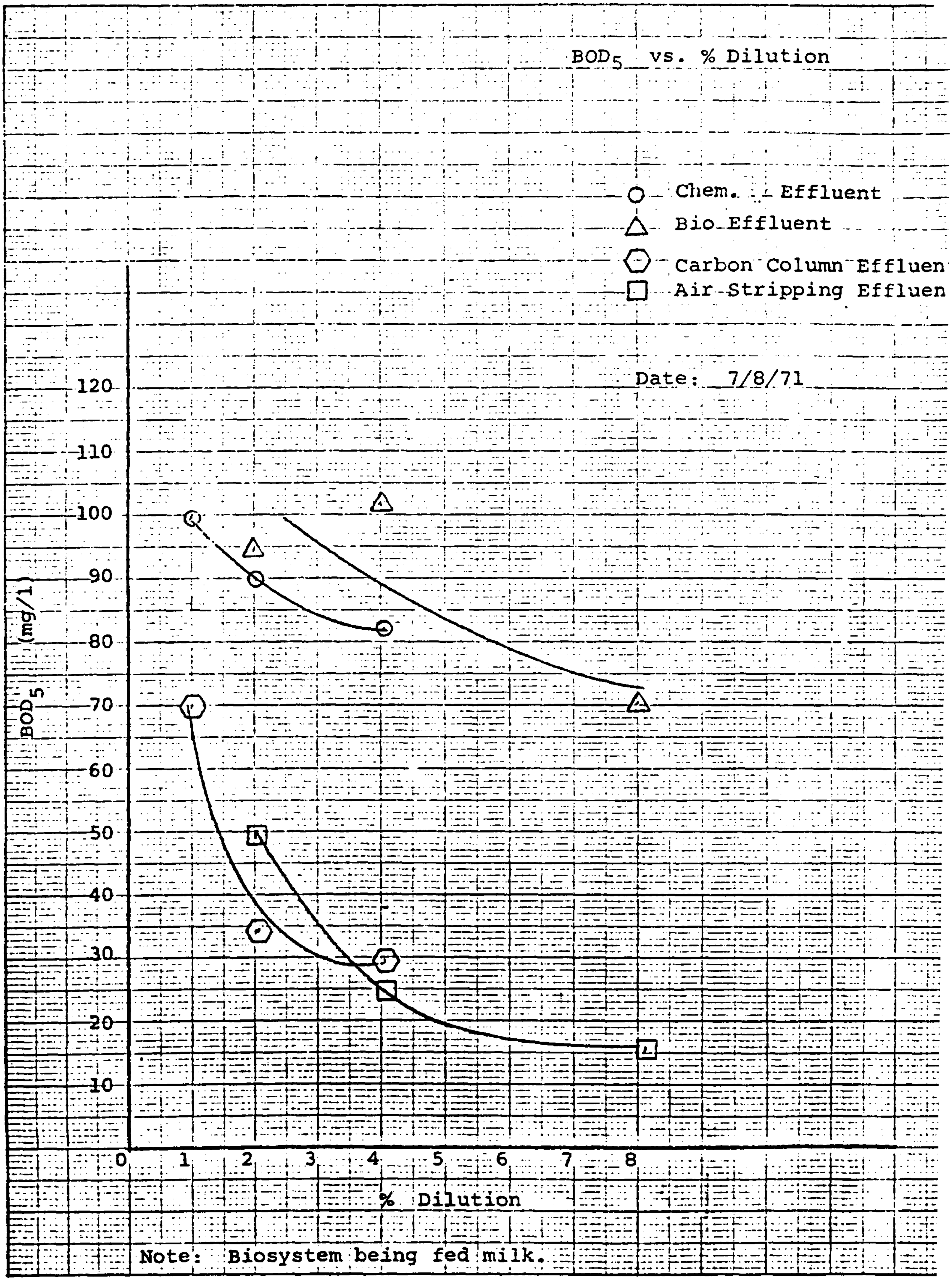

BOD5 vs. % Dilution
Chem. Effluent
Bio Effluent
Carbon Column Effluen
Air Stripping Effluen
Date: 7/8/71
120
110
100
90
80
70
60
50
40
30
20
10
BOD5 (mg/1)
0
1
2
3
4
5
6
7
8
% Dilution
Note: Biosystem being fed milk.

Figure 31

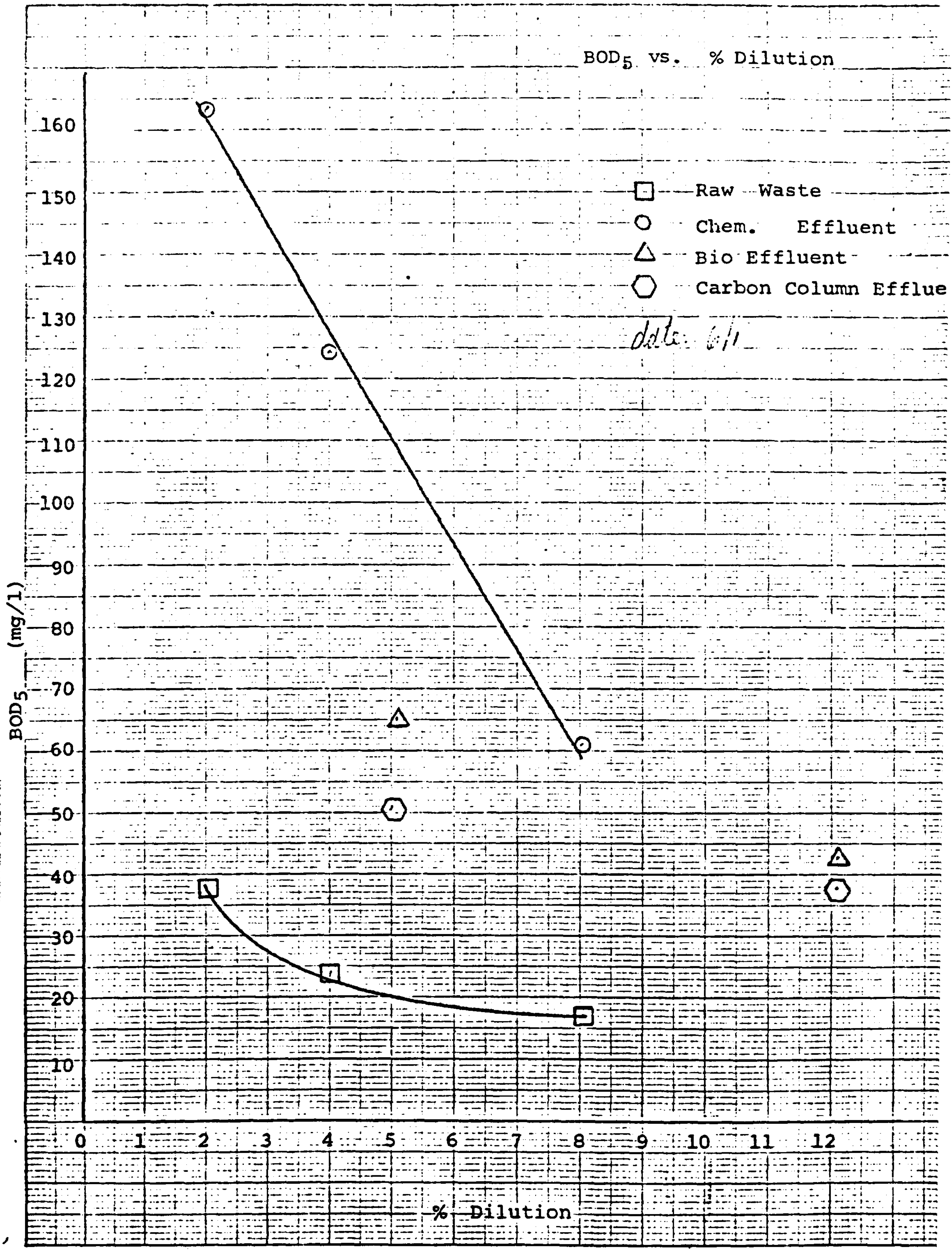

BOD$_5$ vs. % Dilution
Raw Waste
Chem. Effluent
Bio Effluent
Carbon Column Efflue
date: 6/1
BOD$_5$ (mg/1)
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
1
2
3
4
5
6
7
8
9
10
11
12
% Dilution

Figure 32

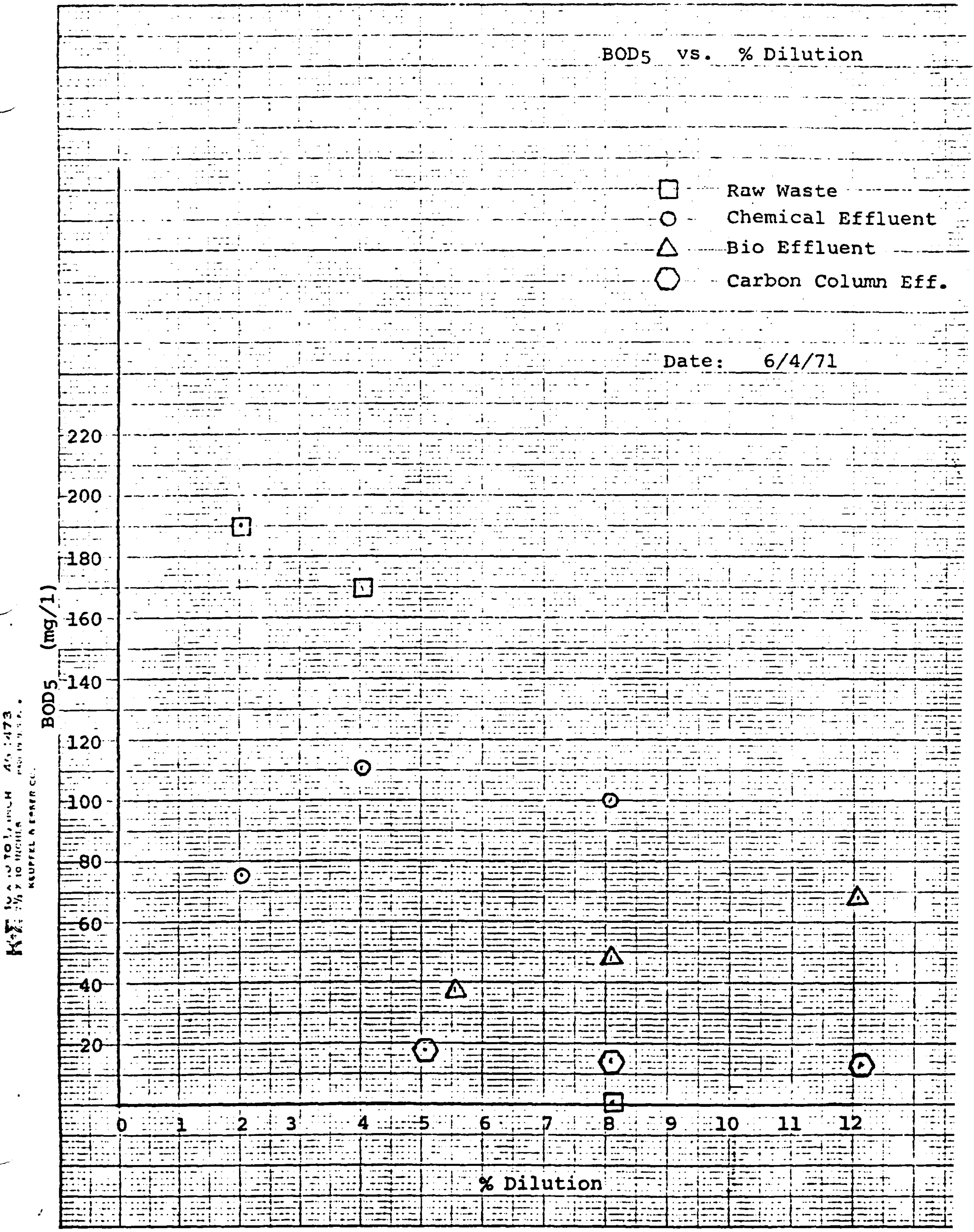
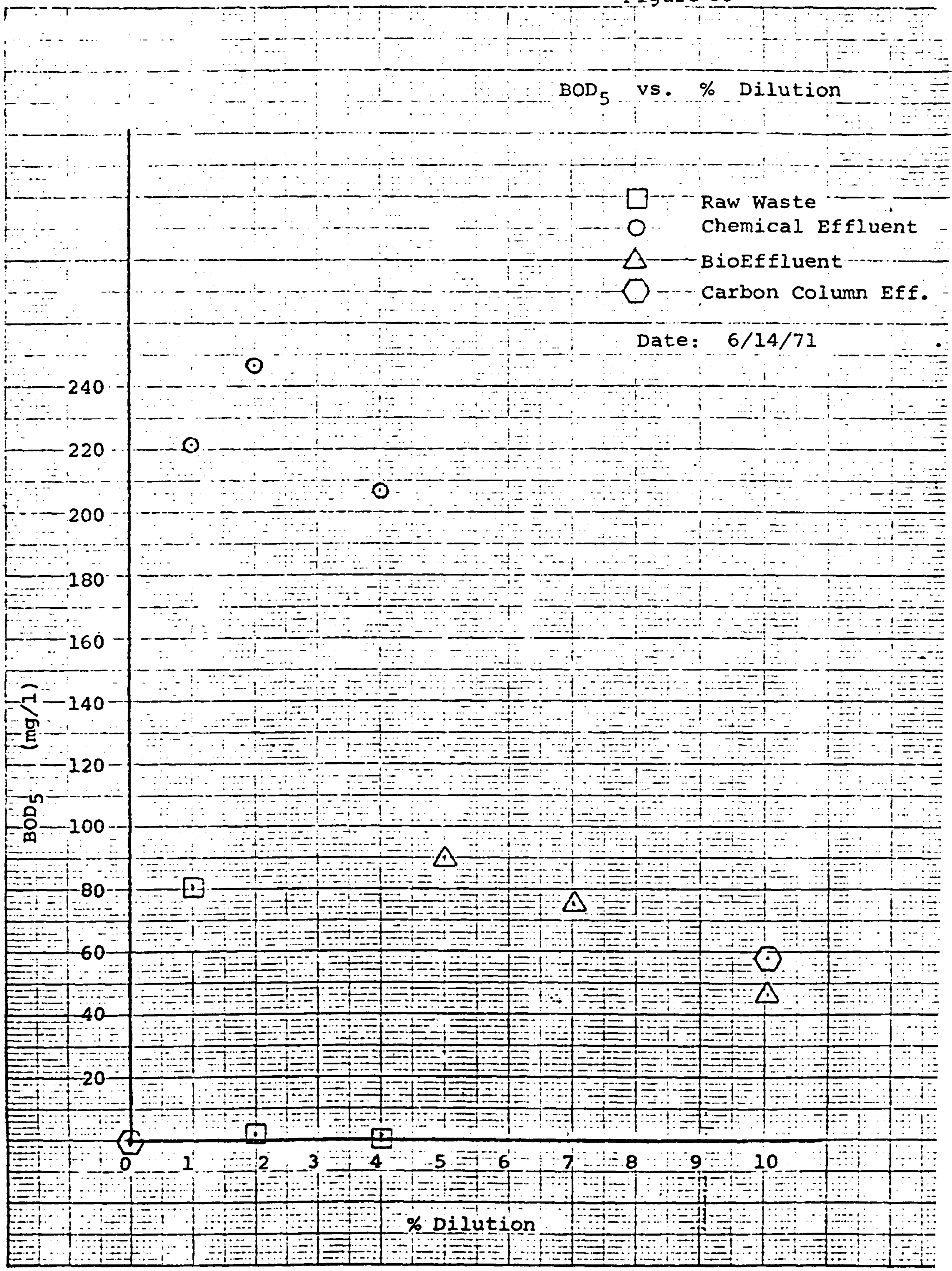

BOD5 vs. % Dilution
Raw Waste
Chemical Effluent
Bio Effluent
Carbon Column Eff.
Date: 6/4/71
BOD5 (mg/1)
220
200
180
160
140
120
100
80
60
40
20
0
1
2
3
4
5
6
7
8
9
10
11
12
% Dilution

Figure 33

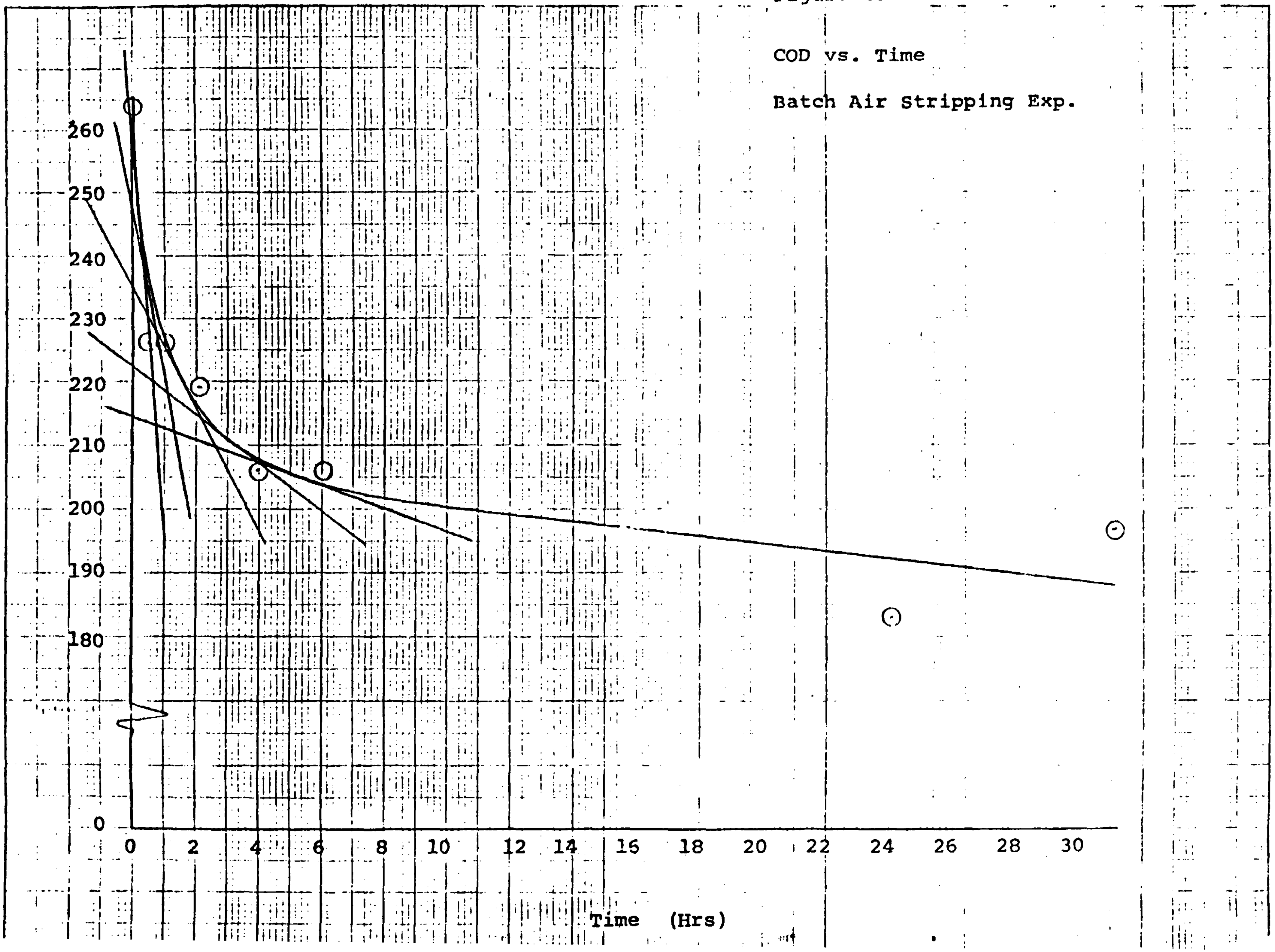


BOD5 vs. % Dilution
Raw Waste
Chemical Effluent
BioEffluent
Carbon Column Eff.
Date: 6/14/71
240
220
200
180
160
140
120
100
80
60
40
20
BOD5 (mg/1)
0
1
2
3
4
5
6
7
8
9
10
% Dilution

Figure 43

COD vs. Time

Batch Air Stripping Exp.



ACTIVATED CARBON INVESTIGATIONS

1. Background Information (Introduction); Reasons for Experimentation

2. Preliminary Isotherms

3. Preliminary Column Screening

4. Pilot Scale Studies
   - A. BDST Explained
   - B. Discussion of Results
     1. Color & BOD Removal
     2. Heavy Metals Removal
     3. BOD_5 Removal
     4. Phenols Removal

5. Final Column Screening

6. Regeneration Studies
   - A. Isotherm Testing
   - B. Column Exhaustion Studies

7. Economic Analyses

8. Exhibits
   - A. Darco Regenerated Carbon Isotherms
   - B. Darco Carbon Regeneration Conditions
   - C. Witco Carbon Regeneration
   - D. Computer Cost Estimates
   - E. Dayton Analysis of Regeneration Off-Gases
   - F. Master Data Tables, Pilot Scale Carbon Column Studies

ACTIVATED CARBON INVESTIGATIONS

During the course of the on-site and pilot plant studies conducted for the Village of Sauget, Illinois, extensive investigations into activated carbon treatment were conducted. These investigations were initiated for the following reasons:

1. The low BOD/COD ratio indicated that a viable biological population might be difficult to maintain.

2. Biological treatment will remove very little, if any, of the color bodies in the waste.

3. Phenol effluent standards would not be attainable with bio-treatment.

4. General waste inhibition* to bio-treatment was expected to cause severe roadblocks to biological treatment.

Investigations of biological treatment confirmed, in varying degrees, all of the above mentioned problems.

The carbon studies were conducted in the following sequence:

A. Preliminary Isotherms

B. Preliminary Bench Scale Column Studies

C. Pilot Scale Column Studies / Regenerated Carbon Studies — Concurrent

D. Final Column Screening

These individual experimental steps are discussed in more detail in the subsections below with additional pertinent discussions including BOD_5, heavy metals and phenol removal.

*i.e.: Chlorine, heavy metals, slow to degrade organics, etc., content of the waste.

A. Preliminary Isotherms

Preliminary feasibility and carbon screening studies were conducted in the form of several batch isotherm (Freundlich) experiments. These batch isotherms consisted of contacting selected composite waste samples with varying quantities of pulverized (passed thru 325 mesh screen) granular carbons from several manufacturers. From the Darco (Atlas Chemical), Landgard, Nuchar and Pittsburgh (Calgon) samples tested, the Darco carbon exhibited superior kinetic and capacity characteristics. The calculated C_0 capacity for the Darco carbon was 10 lbs carbon 1000 gallons processed. These preliminary isotherms were used as a basis for the next screening step: continuous-flow column testing in 1 & 3/4" diameter columns to compare predicted capacity in continuous operation with actual capacity.

For more complete data and analysis of the isotherms experiments, the reader is referred to the "Preliminary Laboratory and In-Plant Studies" reported dated July 20, 1971.

B. Preliminary Bench Scale Column Studies

The initial isotherm surveys were followed by two continuous bench scale column studies using the Darco carbon. The first single column test indicated a carbon loading of 8.5 lbs/1000 gallons processed. The second two-column (in series) experiment indicated a loading factor of 4.3 lb of carbon/1000 gallons processed. These two preliminary experiments are also discussed in detail in the July 20, 1971 lab studies report.

C. Pilot-Scale Column Studies

In order to obtain the best possible design information, a series of four pilot-scale, multiple column experiments were conducted.

The series column experimental apparatus was chosen as best for application on the Sauget waste for the following reasons:

1. Some of the preliminary data indicated that gradual breakthrough could be expected.

2. Best economics are attainable when the carbon is completely exhausted, as with a series system.

3. High effluent purity was required.

All pilot plant data was analyzed using the Bed Depth-Service Time (BDST) method. Before describing the experimental results, a brief explanation of this evaluation technique will be made.

BDST Analysis

The BDST analysis is a data evaluation technique used with multiple column (in series) exhaustion studies to design a commercial scale facility. Evaluation of carbon system total cost (operating and per annum capital value) versus volume flow rate through the plant yields some minimum cost system for the particular waste-carbon system studied.

The BDST experimental data are evaluated for each column flow rate* (V_b) tested in the following manner:

1. Multiple series-column exhaustion curves are determined as plots of some critical parameter (such as color) versus volume of waste processed (see example curves, Figure 44).

2. From these breakthrough curves is determined the service time (volume processed until breakthrough) for several bed depths.

3. A plot of bed depth versus service time is constructed. (See Figure 45, for example).

*In bed volumes/hour.

4. From the BDST curve the Y-intercept, B ("critical bed depth,") and slope, A, are determined.

5. These data, coupled with the commercial plant flow rate (V), are the input design parameters for a computer program prepared by Atlas Chemical Company. This program is used to optimize the commercial system design and estimate capital and operating costs for carbon.

6. The computer estimates are made for several different "V_b's" by modifying the BDST equation ($T = A X + B$) as follows:

$$T = A' X + B \qquad (1)$$

where,

$$A' = A \frac{V_b}{V_b'} \qquad (2)$$

and,

V_b = original linear flow rate
V_b' = new linear flow rate
A = BDST slope an experimental flow rate
A' = BDST slope at new non-measured flow V rate

7. Depending upon the application and the applicable financial policies, an annual value is assigned to the capital cost (variable from 5 to 40%).

8. A plot of total annual operating cost (capital plus operating costs) is made versus volume flow rate (V_b), yielding a minimum total operating cost at some V_b.

9. The V_b of minimum total facility cost and its associated exhaustion curves (used to determine V_a, the volume treated before breakthrough in gallons) are then used as the basis for final process design.

Using V_a and V_b as determined in 8 above along with the commercial scale flow in rate in gal./hr., V and the carbon bulk density in lb/ft^3, D; the following design parameters are calculated:

1. Full-scale bed volume in ft^3, B:

$$B = \frac{V}{7.48 \cdot V_b}$$

2. Carbon weight, W:

$$W = B \cdot D$$

3. Service time in hours, T:

$$T = \frac{V_a \cdot D}{7.48 \cdot V_b}$$

4. Carbon regeneration rate, R_R:

$$R_R = \frac{W}{T}$$

Since the Sauget carbon system must be operated continuously and the total required bed depth would be quite large, this bed depth must be divided among several columns. The column exhaustion curves provide the information necessary to determine the number of columns needed. This column requirement is determined by the necessity for the last column to reach the breakthrough concentration just as the lead column becomes completely exhausted, keeping in mind that one column must be offline at all times for unloading of the exhausted carbon and reloading of regenerated carbon.

Although pressure drop information is required for final system design, the proposed Sauget carbon treatment system calls for sand filtration before the adsorption system to remove suspended solids to prevent bed plugging. Another possible source of bed plugging could be biological growth on the carbon. Such a growth would be primarily a function of column cycle time, bio-growth rate and BOD loading rate. Since the Sauget waste stream is generally low in BOD and composed of many materials exhibiting slow degradation rates, bio-growth is not expected to cause any operational problems unless quite long column service times are required. The pressure drop in the carbon system would therefore be very close to that for the carbon and hardware only, since no bed plugging should occur.

The final information required for design of a carbon system is regeneration data. This information is discussed in a subsequent subsection.

Discussion of Results

Color and COD Removal - Design Bases

Three experiments were performed using multiple (three or four), series four inch diameter columns. The modes of operation employed and the sequence of operations are shown in Figures 3 and 4 respectively. Drawings 3-10 and 3-11 show the pilot plant configuration, including the carbon columns and their sampling points. Each column contained approximately eight pounds of carbon with a bed depth of approximately four feet. The use of large diameter (4 inches) columns allowed the study of a system which could best approximate the performance of a full-scale system. Design parameters obtained from this system were the best possible without greatly increased experimental costs. As an added advantage, sufficiently large quantities of carbon were exhausted to enable regeneration experiments to be conducted, including characteristic regenerated carbon curves (see subsection D).

(The reader is referred to Figures 44 through 52 for the following discussion).

The characteristic exhaustion curves were obtained for the Sauget waste waters (after neutralization and primary chemical treatment) for three volumetric flow rates (expressed in bed volumes per hour): 1.0, 1.9 and 2.3* bed volumes per hour. In each of these experiments color and COD were monitored throughout as the critical design parameters.**

*These flow rates are the average total flows based upon the total volume processed divided by the total hours on stream and the total carbon bed volume.

**BOD_5 is a critical design parameter and is known to breakthrough first. This problem is discussed fully in a later portion of this report.

In all experiments the color breakthrough was chosen as 30 APHA units and the COD breakthrough as 100 mg/l. The color breakthrough was chosen based upon the statement of Mr. Carl Blomgren of the Illinois EPA Standard's Division that past rulings of the Pollution Control Board on effluent color criteria were generally the same as the receiving stream quality criteria. Since selected maximum measured (true) color values for the Mississippi River above East St. Louis ranged 22 to 32 APHA, 30 units was projected to be very close to the final standard, when issued. The COD breakthrough value of 100 mg/l was arbitrarily fixed based upon the fact that the color breakthrough of 30 APHA units occurred at approximately 100 mg/l COD concentration. No COD standard is presently in force or predicted for the Sauget effluent

Figures 44 and 46 show the characteristic exhaustion curves obtained from May 10 through May 21 run. The service time for each of the three columns is determined by dividing the total volume processed until breakthrough by the average flow rate in gallons per hour.

The service times for both color and COD were then plotted versus bed depths to obtain the BDST graph, Figure 45.

Similarly, the exhaustion curves for the runs of 5/29/71 through 6/14/71 and 6/16/71 through 7/16/71 (1.88 and 0.99 bed volumes per hour, respectively) were plotted. Figures 47 through 52 show the characteristic exhaustion and BDST curves for these trials.

The data from the BDST curves are summarized in Table 83 . The type of data is used in the computer program to make design calculations and capital and operating cost estimates for a carbon treatment system (assuming no change in carbon adsorption characteristics after regeneration). The economic analysis for carbon treatment based upon this pilot plant data is discussed later in this context.

Since multiple column exhaustion studies were performed at three different flow rates, a check of the theoretical equations ((1) and (2), page 254) is possible. Table 84 shows excellent agreement for COD "B" values in runs I and II. However, COD values for runs II and III and all color values show poor

TABLE 84

COMPARISON OF CALCULATED BDST SLOPES TO MEASURED VALUES

Run No.	V (Meas. Flow)	V^1 (New Flow)	A^1 New BDST Slope	A Measured BDST Slope
I (COD)	26.8	27.7	9.49	12.0
I (COD)	26.8	14.8	17.8	16.0
I (Color)	26.8	27.7	14.2	19.1
I (Color)	26.8	14.8	26.6	33.3
II (COD)	27.7	14.8	22.5	16.0
II (Color)	27.7	14.8	35.7	33.3

comparisons. The BDST "A" values (slopes) were calculated for "new" flow rates and compared the actual measured values. As may be seen in Table 84 , the comparisons are quite good, with the maximum error between "theoretical" and measured values being roughly 30%.

Heavy Metals Removal

The prime removal steps for heavy metals in the treatment of the Village waste waters are the lime neutralization - coagulation - sedimentation steps. Insoluble heavy metal hydroxides are precipitated and removed in these steps. However, minute, non-settleable solids and residual solubility cause some escape of heavy metals from these steps. During the pilot plant studies the amount of heavy metals escape from the chemical system and the ability of the carbon system to capture them was measured. Chemical system effluent and carbon column effluent heavy metals contents were measured on several occasions during the studies. These data are shown in Tables 85 and 86 .

Table 86 , comparing carbon column feed and effluent without sand filtration, shows removal of Fe, Ni, and Zn; increase in Mn, B and Ba; no change in the remaining items.

Table 85 shows removals of Cd, Fe, Mn, Ni and Zn, after sand filtration was added as an intermediate treatment step.

The removals indicated by Table 86 are probably occurring by two mechanisms: filtration of small precipitate particles and adsorption (reaction with) of dissolved ions. In Table 85, however, the metals removals by carbon are expected to be primarily by the adsorption route, since metals removal by filtration should be almost 100% complete in the filter beds.

The chemical system effluent copper content was measured 60 times during the pilot plant studies yielding a mean concentration of 0.12 ppm and a range of values from 0.01 to 1.4 ppm. The copper content of the carbon column effluent (without filtration) was measured fifteen times yielding an average value of < 0.01 ppm and a range of values from < 0.01 to 0.10. Twenty carbon column effluent copper values measured by atomic absorption on 9/10 and 9/11/71 averaged 0.063 mg/l with a range of < 0.02 to 0.13 mg/l. These values were measured on effluents

TABLE 83

BDST DESIGN DATA

Run No.	Dates	Parameter	(Feet) X-Intercept	(Hours) Y-Intercept	Slope	Linear Flow Velocity Ft./Hr.
I	5/10 - 5/21/71	COD	0.51	-5.0	9.81	26.8
		Color	1.22	-17.8	14.7	
II	5/29 - 6/14/71	COD	0.52	-5.5	12.0	27.7
		Color	2.4	-44.5	19.1	
III	6/16 - 7/16/71	COD	2.75	-43.0	16.0	14.8
		Color	2.22	-75.0	33.3	

TABLE 85

COMPARISON OF SAND FILTER EFFLUENT AND CARBON COLUMN EFFLUENT
PILOT PLANT PERFORMANCE DESIGN RUN

	Sand Filter			Carbon Columns					
Metal	#1	#2	#3	#1	#2	#3	#4	#5	#6
Ba	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Cd	0.15	N.D.	N.D.	N.D.	N.D.	0.36	N.D.	N.D.	N.D.
Cr (VI)	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Cr (Tot.)	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Cu	0.3	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Fe (Dis.)	0.2	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Fe (Tot.)	1.1	3.6	N.D.	0.38	N.D.	N.D.	N.D.	N.D.	N.D.
Pb	N.D.	N.D.	N.D.	0.12	N.D.	0.7	N.D.	N.D.	0.5
Mn	0.7	N.D.	N.D.	0.5	N.D.	0.2	N.D.	N.D.	0.2
Ni	0.2	N.D.	N.D.	0.2	N.D.	N.D.	N.D.	N.D.	N.D.
Se	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
As.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Ag	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Zn	2.3	N.D.	N.D.	0.52	N.D.	2.0	N.D.	N.D.	0.66

TABLE 86

COMPARISON OF CHEMICAL SYSTEM EFFLUENT AND CARBON COLUMN EFFLUENT HEAVY METALS CONTENTS, 6/24/71

Metal	Chemical System Effluent	Carbon Column Effluent
Cr (VI)	N.D.	N.D.
Cr (Tot.)	N.D.	N.D.
Fe (Dis.)	N.D.	N.D.
Fe (Tot.)	0.50	N.D.
Cu	N.D.	N.D.
Ni	0.53	N.D.
Mn	0.70	2.6
Zn	13.0	N.D.
Cd	0.093	N.D.
B	0.40	1.0
Ba	N.D.	1.8
Pb	N.D.	N.D.
Ag	N.D.	N.D.
Se	N.D.	N.D.
As.	0.14	0.20

from two parallel-operated columns, one containing Darco virgin carbon and the second Darco regenerated carbon.

Whether the removal mechanism of the carbon is by filtration or by adsorption, the effect of metals build-up on carbon efficiency (caused by multiple exhaustions and regenerations) is unknown; reduced efficiency in heavy metals and organic removal is a strong possibility due to salt build-up. Further effects on carbon efficiency can be caused by precipitation of calcium salts on the carbon from super-saturated solutions which could enter the carbon system. Regeneration studies (see Section D) have indicated that such speculation may be valid: acid wash of once regenerated carbon caused a marked improvement in the carbon's performance.

Heavy metals criteria may be met with a greater degree of confidence after treatment with virgin carbon, but metals build-up may cause reduced capacity in the regenerated carbon. Acid wash of regenerated carbon may be required to prevent losses in adsorption capacity. If acid wash of the regenerated carbon were used for commercial scale carbon regeneration, the spent acid would be recycled to the head of the treatment system. The major heavy metals removal mechanism of activated carbon is probably by filtration, although some adsorption removals also may occur (assuming no prior sand filtration step).

BOD_5

One of the major effluent quality standards which the Village discharge is required to meet is a BOD_5 concentration of 20 mg/l or less. The ability and reliability of a "total"* Village treatment system to meet this criterion must be evaluated. The proposed carbon adsorption system must be able to meet this standard, since no other soluble BOD_5 removal operation is included in such a "end-of-pipe" treatment scheme. Tables 87 and 88 summerize and compare the effluent BOD_5 information obtained during the pilot plant studies. Table 87 shows column effluent BOD_5 values before either color or COD breakthrough. Table 88 shows values measured after breakthrough.

*Chemical plus carbon systems.

TABLE 87

EFFLUENT BOD_5 VALUES BEFORE COLOR OR COD BREAKTHROUGH*

Date	Sample	Chemical System BOD_5	Carbon Column BOD_5	Carbon Column COD	Carbon Column Color	% BOD_5 Removal
5/30	Col. IV Eff.	101	54	4	-	47%
5/31	"	130	38	0	-	71%
6/1	"	143	45	0	10	69%
6/2	"	155	66	0	10	57%
6/4	"	95	15	-	10	84%
6/5	"	83	13	88	10	84%
6/6	"	77	20	46	10	74%
6/7	"	92	57	92	-	38%
6/17	Cal. II Eff.	93	25	40	10	73%
6/17	Col. IV Eff.	93	25	48	-	73%
6/18	"	126	20	27	-	84%
6/22	"	82	18	-	10	78%
6/29	"	102	120	-	20	Incr.**
11/16	1st Regen. A.W.	-	29	12	10	-
11/17	"	-	51	20	10	-
11/18	"	-	64	96	10	-
11/18	"	-	54	28	10	-
11/16	Virgin C	-	36	5	10	-
11/17	"	-	36	79	10	-
11/18	"	-	63	88	30	-
11/16	1st Regen.	-	24	24	10	-
11/17	"	-	47	24	10	-
11/18	"	-	60	58	10	-
11/18	"	-	57	42	30	-
11/16	3rd Regen.	-	43	32	10	-
11/17	"	-	92	-	20	-
11/17	"	-	81	36	20	-
11/17	"	-	88	36	20	-

*Breakthrough for color = 30 APHA units
Breakthrough for COD = 100 mg/l

**Incr. = BOD_5 higher after carbon treatment than before

TABLE 88

BOD$_5$ VALUES AFTER
COLOR AND COD BREAKTHROUGH

Date	Sample	Chemical System BOD$_5$	Carbon Column BOD$_5$	Carbon Column COD	Carbon Column Color	% BOD$_5$ Removal
6/8	Col. IV Eff.	95	59	135	20	38%
6/9	"	79	42	164	30	47%
6/10	"	55	44	111	125	20%
6/13	"	48	68	-	-	Incr.*
6/18	Col. II Eff.	126	20	108	10	84%
6/27	Col. III Eff.	63	5	144	10	92%
7/7	Col. IV Eff.	75	26	200	-	65%
7/7	"	75	44	-	-	41%
7/8	"	91	45	-	-	51%
7/9	"	110	102	-	-	7%
7/10	"	46	30	133	-	35%
7/11	"	32	52	205	90	Incr.
7/12	"	45	46	258	90	Incr.
7/13	"	-	30	182	100	-
7/14	"	31	49	-	150	Incr.
7/14	"	31	90	-	-	Incr.
7/15	"	56	83	225	200	Incr.
7/16	"	45	102	215	275	Incr.

*Incr. = BOD$_5$ higher after carbon treatment than before treatment

Referring to Table 87, it may be seen that an effluent BOD_5 concentration of 20 mg/l was attained 18% of the time and 40 mg/l 43% of the time (before breakthrough of color or COD). During the period between 5/30/71 and 6/19/71 the BOD removal efficiency ranged from a maximum of 84% to an increase in BOD_5 concentration after carbon treatment. (This phenomenon was observed on seven occasions after color and COD breakthrough. See Table 88.) From these data it may be concluded that although carbon treatment of the Village of Sauget effluent waste waters is capable of some BOD_5 reduction, it (carbon treatment) is definitely not reliable. In fact, carbon may at times remove some inhibitory compounds, resulting in an apparent rise in the final effluent BOD_5. It is felt that the BOD_5 escaping carbon removal is primarily in the form of low molecular weight compounds (for instance, methanol) which are very water soluble and therefore poorly adsorbed. If carbon is to be considered for treatment of the Village waste, such compounds may have to be removed at their source to enable meeting the effluent BOD_5 criterion.

The use of a "second-stage" adsorption system using small-pore carbon to preferentially adsorb low molecular weight compounds could be considered as an alternate to in-plant reduction of low molecular weight compounds. Such a system was not investigated and its feasibility is not known. The carbon from such a system would require either a separate regeneration facility; a change in the regeneration conditions for the main facility, or discard of the exhausted carbon. Any of the choices would cause increased operation problems and costs.

Phenol

The State of Illinois effluent criteria presently requires effluent phenol concentrations not to exceed 0.3 ppm. This standard can be met quite consistently by a carbon adsorption system as indicated by the data in Table 89, if phenol values are measured by the 4-aminoantipyrene test.

TABLE 89

PHENOL CONCENTRATIONS BEFORE COLOR OR COD BREAKTHROUGH

Date	Sample	Phenol (mg/l)
5/17	Col. IV Eff.	0.15
6/4	"	0.15
6/5	"	0.15
6/27	"	0.05
11/16	1st Regeneration (AW)	0.1
11/16	1st Regeneration	0.15
11/17	Virgin	0.1
11/17	3rd Regeneration	0.1

Average influent (chemical system effluent)

Concentration = 3.9 mg/l

C. Regenerated Carbon Studies

In order for a carbon adsorption treatment facility with high carbon usage to approach economic feasibility, the exhausted carbon must be reused. Since the relative carbon capacity may change after regeneration, virgin carbon capacity may not be adequate for choice of a carbon or for final system design. Carbon reuse is effected by regenerating, usually at high temperature (carbon can be steam, biologically, chemically, etc. regenerated also). To drive off organics and to obtain the surface characteristics and structure similar to the virgin carbon, the Sauget exhausted carbon must be regenerated at high temperature (using, for instance, a multiple hearth furnace).

Since the commercial facility will require the carbon to be reused several times, samples of carbon were exhausted and regenerated once, twice and three times to determine the effect of regeneration and reuse on the kinetics and adsorptive capacity of the carbon.

The regenerated carbons were compared to virgin samples of the same carbon sample using characteristic exhaustion curves similar to those used in the virgin carbon BDST analyses and some carbon isotherm work.

Figures 53 and 54 compare the exhaustion curves of Darco virgin and once regenerated* carbons for both color and COD. The rate of adsorption of the carbons on color removal appears almost identical; however, the regenerated carbon appears to perform slightly worse for COD removal.

Also compared in Figures 55 and 56 are color and COD exhaustion curves for Witco virgin and regenerated carbons. In this case, both sets of curves indicate slightly reduced volume processed of the regenerated carbon before parameter breakthrough is reached.

Figures 57 and 58 compare samples of Darco virgin, once regenerated and acid-washed once regenerated carbons.

*See Exhibit C for description of Atlas Chemical Company and Witco Chemical Company regeneration conditions.

These exhaustion curves show greater volumes processed before color and COD breakthrough of the regenerated and acid washed regenerated compared to the virgin carbon.

Twice regenerated Darco carbon is compared to the virgin in the exhaustion curves in Figures 59 and 60. Again, the color removal capability seems relatively unchanged before breakthrough, while COD removal is slightly worse.

Figures 61 and 62 compare Darco virgin to thrice regenerated carbon. In this final case, the regenerated carbon performance is substantially worse in that both color and COD breakthrough are reached much sooner in the regenerated carbon than in the virgin.

The single column exhaustion curves shown in Figures 54 through 62 do provide an indication of changes in the carbon adsorptive surface by the changes in adsorptive capacity before breakthrough; however, these curves do not show the effects of multiple regeneration on ultimate adsorptive capacity. In individual cases (such as in Figure 53 or Figure 59) the column performances are so nearly identical, the estimate that ultimate capacities are not substantially different might be made with some degree of safety.

A carbon isotherm run by Atlas Chemical Company on an early sample sent for regeneration is shown in Exhibit A. The carbon use cannot be calculated from the graph, but the line slopes (and Atlas conclusions) indicate approximately equivalent ultimate capacities for the two carbons compared.

The "first regeneration" sample sent to Atlas late in October, 1971, (see Exhibit B) showed higher molasses and iodine numbers, the major indicators of carbon adsorptive capacity (other than actual waste performance tests), than the virgin carbon. These numbers indicate approximately equivalent capacities for the virgin and once regenerated carbons. It should be noted that there is a sharp change in the carbon pH (from 4.6 before regeneration to 10.6 after). This pH change could account for any changes in the carbons' single-column performance comparison.

No isotherm comparisons are available for the Witco carbon regenerations. However, as indicated in Exhibit C, measurements made by Witco personnel led them to the conclusion that the regenerated carbon properties were similar to those of the virgin carbon.

Comparison of the regeneration conditions and carbon characteristics for the three Darco samples (1st, 2nd, and 3rd regenerations) are shown in the Atlas Chemical Company letter of May 17, 1972 (see Exhibit C). The letter discusses the conditions of regeneration and the resulting carbon character. The writer, Mr. Roy A. Hutchins of Atlas also speculates as to the causes of the changed carbon properties. Referring to the analysis comparison table, the most disturbing change from progressive regenerations is the "Grams of Sorbed Material per Gram of Carbon."* These values show an apparent substantial reduction in the carbon adsorptive capacity for materials present in the Village waste stream. Since complete isotherm data is not available for these samples, these capacity numbers are the best available data on carbon capacity (for components present in the Village waste). If the reductions in carbon capacity shown by these data are representative, then a substantial increase in size and cost of carbon facilities for the Sauget application would result.

Although the exact cause of the reduced regenerated carbon performance is not known, the problem appears to be coupled in part to surface coating and pore plugging by oxide carbonate, or other salt coatings and/or surface pH change. This speculation is reinforced by the visibly improved

*Each values in this table should be moved one column to the left.

performance of the acid washed regenerated Darco carbon (even better than the virgin carbon).

Since the economics of a larger capacity carbon system (caused by decreased adsorptive capacity of regenerated carbon) compared to an acid wash step as part of the regeneration procedure have not been evaluated, no recommendation as to the most economical process design can be at this time.

In addition to the feasibility of returning the exhausted carbon to virgin condition the consequences of the regeneration to the furance and the environment must be evaluated. Experiments involving carbon regeneration with off-gas scrubbing and chemical analysis were conducted in Enviro-Chem's Dayton laboratories by Dr. Philip Hayden. These experiments are attached hereto as Exhibit E.

Experiment one included scrubbing of the off-gases with caustic solution. The caustic analysis, after scrubbing showed the accumulation of chlorides. These chlorides may have been captured from HCl evolved during the regeneration process (from the chlorinated hydrocarbons present in the Village waste). If HCl is evolved, the regeneration off-gases may be acidic and quite corrosive in nature, necessitating careful specification of furnace construction materials as well as air pollution abatement equipment.

The second experiment showed that the regeneration off-gases may contain substantial quantities of organics causing potentially severe air pollution problems. The furnace off-gases will undoubtably require some scrubbing, condensation, after burning, or combination of steps to prevent these contaminants from escaping to the environment.

Both experiments indicated that 10-15% of the exhausted carbon is volatile. Since most or all of this weight loss may be in the form of volatilized organic compounds, the air pollution abatement requirements for the regeneration furnace may be quite extensive.

D. <u>Final Carbon Screening</u>

After completing full pilot-scale column studies, several bench scale, continuous-feed column experiments were conducted to obtain the following information:

1. Confirm previous isotherm data.

2. Complete carbon screening using column exhaustion studies.

These experiments were carried out using 1.75" I.D. bench scale columns with a bed depth of approximately 20 inches. The flow rates during the experiments were maintained at approximately 15 bed volumes per hour (~ 200 ml/min). (These relatively high throughput rates were maintained to accelerate breakthrough times, eliminating lengthy experimentation.)

(The reader is referred to Figures 63 through 68 for the following discussion).

The column studies compared three of the more promising carbons (i.e., Witco,* Pittsburgh and Nuchar) to the best performing carbon from the isotherm tests, Darco carbon (Atlas Chemical Company). In all runs the columns were charged with virgin carbon and run in parallel, attempting to keep all operating conditions constant except the carbon itself. Effluent samples, taken at various time intervals as grab samples, were monitored for COD and color, two significant effluent parameters for which analysis is rapid and easy.

Figures 63 and 64 show plots of color and COD respectively versus volume processed for Nuchar Carbon and Darco carbon. In Figure 63 the superiority of the Darco carbon is quite evident. If breakthrough is 30 APHA units, then the Darco carbon would be capable of processing approximately six times as much waste water as the Nuchar carbon ir

*Freundlich isotherms comparing Witco and Darco carbons on the Sauget waste were carried out by Witco Chemical Company and are included in Exhibit C.

a single column application. However, from the curve shapes at 350 + APHA units, the ultimate capacity of the Nuchar carbon appears closer to the Darco carbons performance. The COD curves indicate better kinetics for the Darco carbon, but ultimate capacity comparison is impossible. Figure 64 , a plot of effluent COD vs. volume processed, indicates that the Nuchar carbon may have higher capacity for COD, but slower adsorption kinetics. However, the early breakthrough for COD (100 mg/l) indicates the critical bed depth for both carbons may not have been exceeded for this test.

Figures 65 and 66 are graphs of color and COD volume processed for Darco and Witco carbons. Both plots indicate a "superior" performance by the Darco carbon; the Witco carbon was not able to meet the above mentioned color or COD breakthrough values at any time during the performance run Again, the tests do not indicate ultimate carbon capacities, but do indicate that critical bed depths were not exceeded.

The final performance comparison in this series is shown in Figures 67 and 68 , comparing Darco and Pittsburgh carbons. The breakthrough curves for both color and COD were so similar that no significant difference in the two carbons' adsorption rates was apparent. Again, critical bed depths were not exceeded as indicated by the data. Although all previous column experimentation was conducted using Darco carbon, the similarity of performance shown in this test could provide the advantage of allowing a competitive bidding situation to develop between Atlas Chemical and Calgon Company, if carbon treatment is included in the final Village treatment system.

E. Economic Analysis

The capital and operating economics of a carbon adsorption system are dependent on several parameters. The following list shows the major items influencing capital and operating costs for carbon treatment (assuming the treatment is technically feasible):

1. Waste character (i.e., the weight of carbon required to process a specified waste quantity, water volume, etc.)

2. Type of contactor used (i.e., single fixed-bed column, multiple fixed-bed columns, pulsed bed column, etc.)

3. Contact flow rate (expressed in bed volumes per hour).

4. Regeneration characteristics (operating conditions, rate, losses, etc.)

Using a computer program developed by Atlas Chemical Company capital and operating cost analyses for carbon treatment of the Village effluent were made. The bases for all cost estimates were:

1. 25.0 MGD flow rate.

2. Adsorption characteristics as determined in carbon run number one.

3. No change in carbon characteristics after multiple regenerations.

4. Specific costs (labor, insurance, interest rates, etc.) as specified in the raw computer output (see Exhibit D).

5. All carbon systems will require chemical treatment and filtration for pretreatment.

Using these design bases to fix waste character and some regeneration characteristics, the effect of contactor type and variations in volume flow rate on systems cost were determined. (Due to the inability of a single column fixed-bed system to completely exhaust all carbon before regeneration it was not considered an economically viable alternative and therefore was not evaluated for treatment of the Village waste stream). Table shows the computer capital and operating cost estimates for multiple, fixed-bed columns and for a pulsed bed facility. It should be emphasized that these estimates do not reflect site preparation, foundations and supports, outside battery limits piping and electrical work, painting, general field costs, home office costs, contingencies, etc. which were included in previously reported cost estimates. Figures 69 and 70 show plots of total yearly operating cost versus volume flow rate for the two systems. The least total yearly cost (capital + operating) for the fixed-bed system appears to be at approximately four bed volumes per hour and that for the pulsed bed system at approximately seven bed volumes per hour. Although the pulsed bed system has the best apparent economics (i.e., least total yearly cost) the fixed-bed system was recommended as the best option for the following reasons:

1. The design and operation of a fixed-bed system are better known and documented than the pulsed bed system which represents relatively new technology.

2. Pulsed bed systems, the size proposed for the Village have never been built or operated. The projected capital and regeneration costs used in the computer program are questionable when extrapolated to a system which would be as large as the Village's.

Using the above described design bases plus the following stipulations:

1. 11.5 MGD design flow

2. 4.0 bed volume per hour contactor flow rate

a computer cost estimate for the options shown in Table was made. From these data rough cost sensitivity curves (to COD) were prepared for the two carbon loading rates*

*The higher COD loading rates assume partial COD removal by biological growth on the carbon. Biological growth on Sauget treatment plant carbon would be expected to be very low, if any at all.

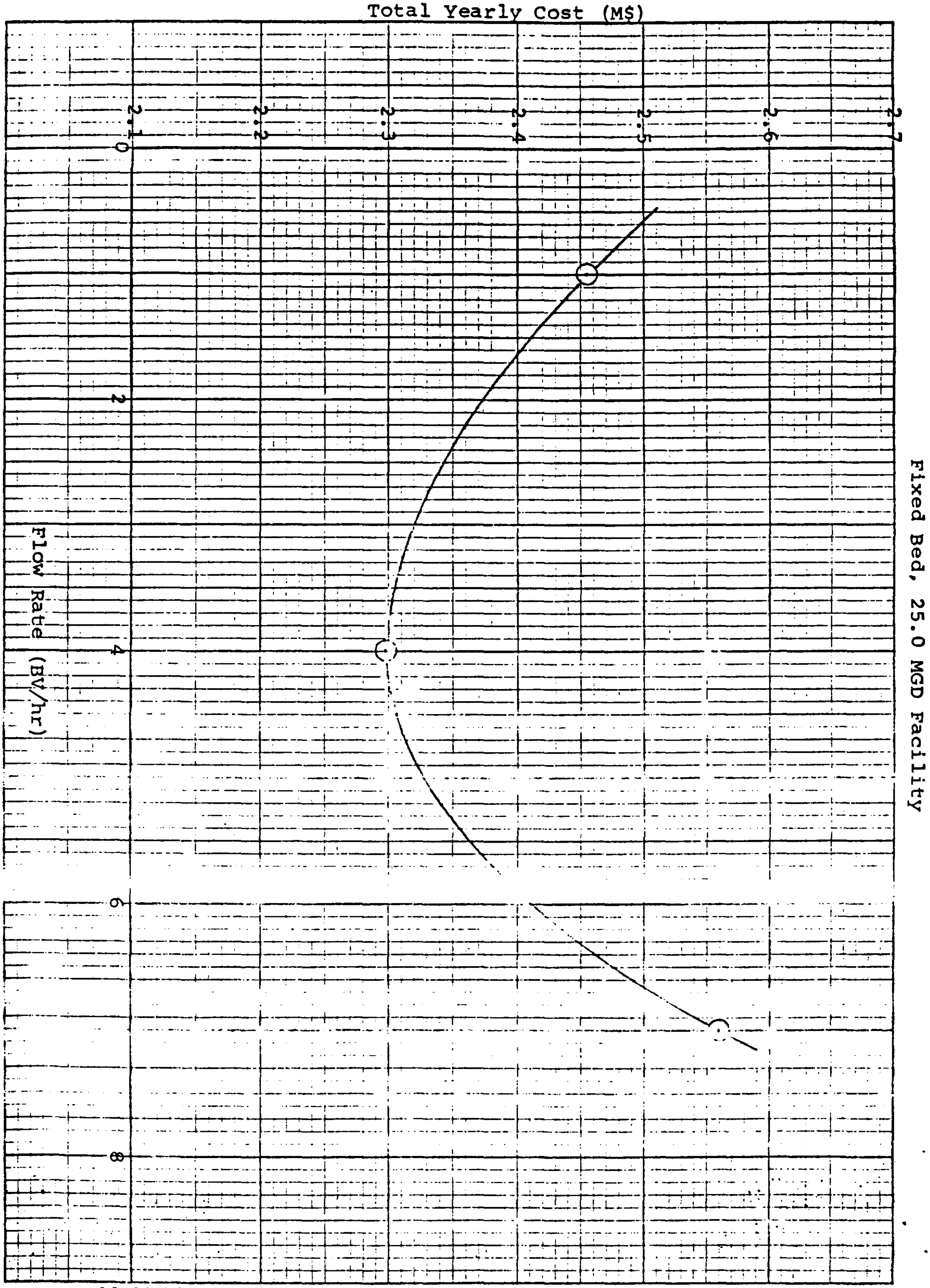

Total Yearly Cost (M$)
2.1
2.2
2.3
2.4
2.5
2.6
2.7
0
2
4
6
8
Flow Rate (BV/hr)
Fixed Bed, 25.0 MGD Facility

FIGURE 69

Pulsed Bed, 25.0 MGD Facility

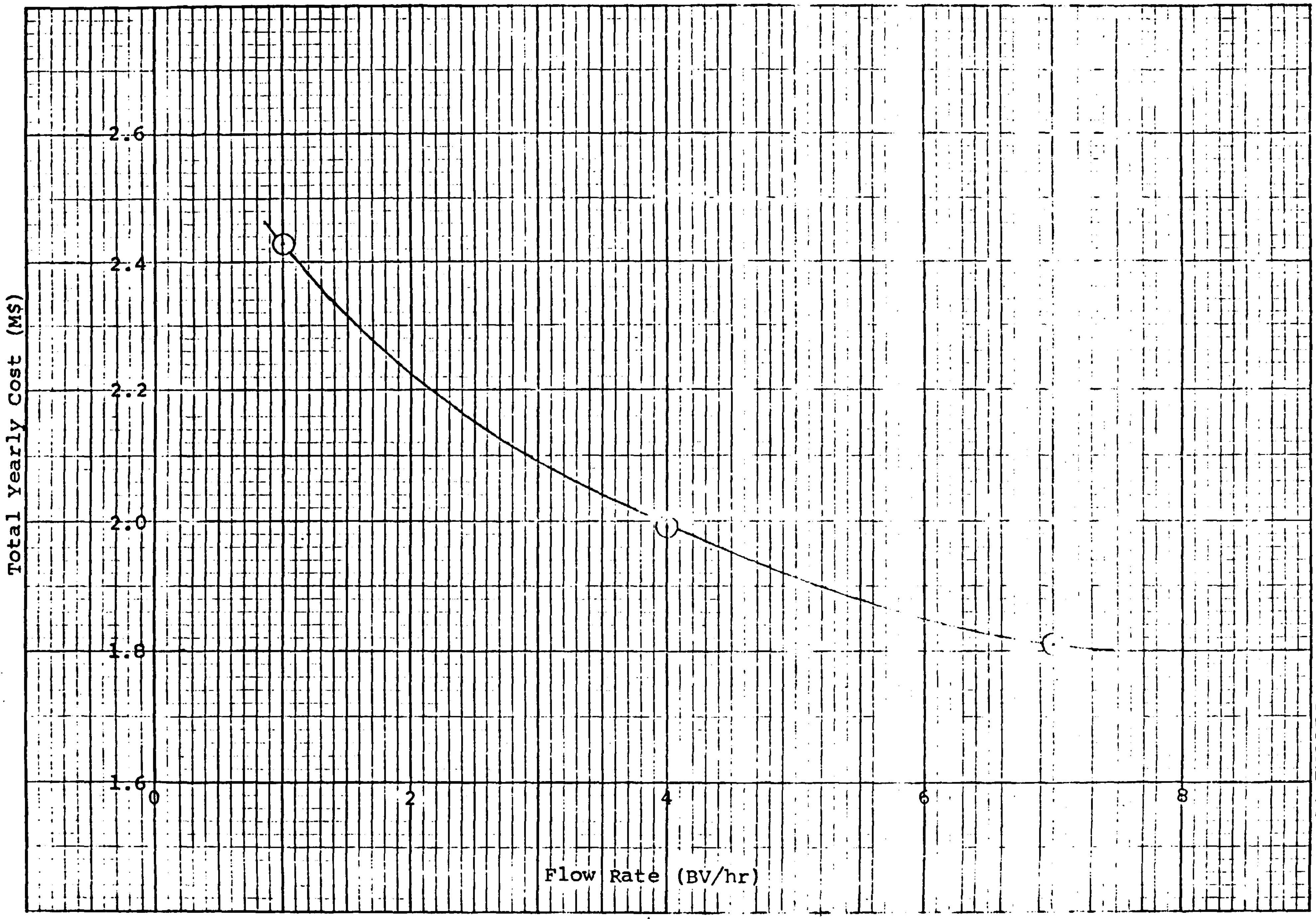


FIGURE 70

TABLE 90

COST SENSITIVITY ANALYSIS
FOR SAUGET CARBON SYSTEM (TO COL. VOLUME FLOW)

Fixed Bed (in M$)

All numbers are based on a municipal account

Flow (BV/hr)	Capital Inst. Cost	Capital C Cost	Total Capital Cost	Operating Direct Cost	Cost of Capital @8.7%/Year	Total Yearly Cost
1.00	4.544	1.067	5.612	1.945	0.509	2.454
4.00	2.713	0.463	3.176	2.010	0.288	2.299
7.00	2.433	0.418	2.851	2.302	0.258	2.560

Pulsed Bed (in M$)

Flow (BV/hr)	Capital Inst. Cost	Capital C Cost	Total Capital Cost	Operating Direct Cost	Cost of Capital @8.7%/Year	Total Yearly Cost
1.00	4.755	1.058	5.813	1.900	0.527	2.427
4.00	2.098	0.420	2.518	1.665	0.228	1.893
7.00	1.683	0.329	2.012	1.629	0.183	1.811

TABLE 91

CARBON TREATMENT COST ESTIMATES FOR
VILLAGE OF SAUGET EFFLUENT WASTE WATERS

Case No.	Carbon Loading Rate In lb/COD/lb Carbon	lb COD Treated /Day	Flow Rate MGD	Total Cap. Cost M$	Direct Op. Cost M$/Yr	Total Operating Cost M$/Yr*
1	0.11	50,000	11.5	3.187	2.941	3.230
2	0.11	25,000	"	2.147	1.271	1.466
3	0.05	12,500	"	1.684	0.669	0.822
1A	0.22	50,000	"	2.381	1.614	1.830
2A	0.22	25,000	"	1.728	0.722	0.879
3A	0.10	12,500	"	1.485	0.399	0.534

*Amortization at 8.7%/year

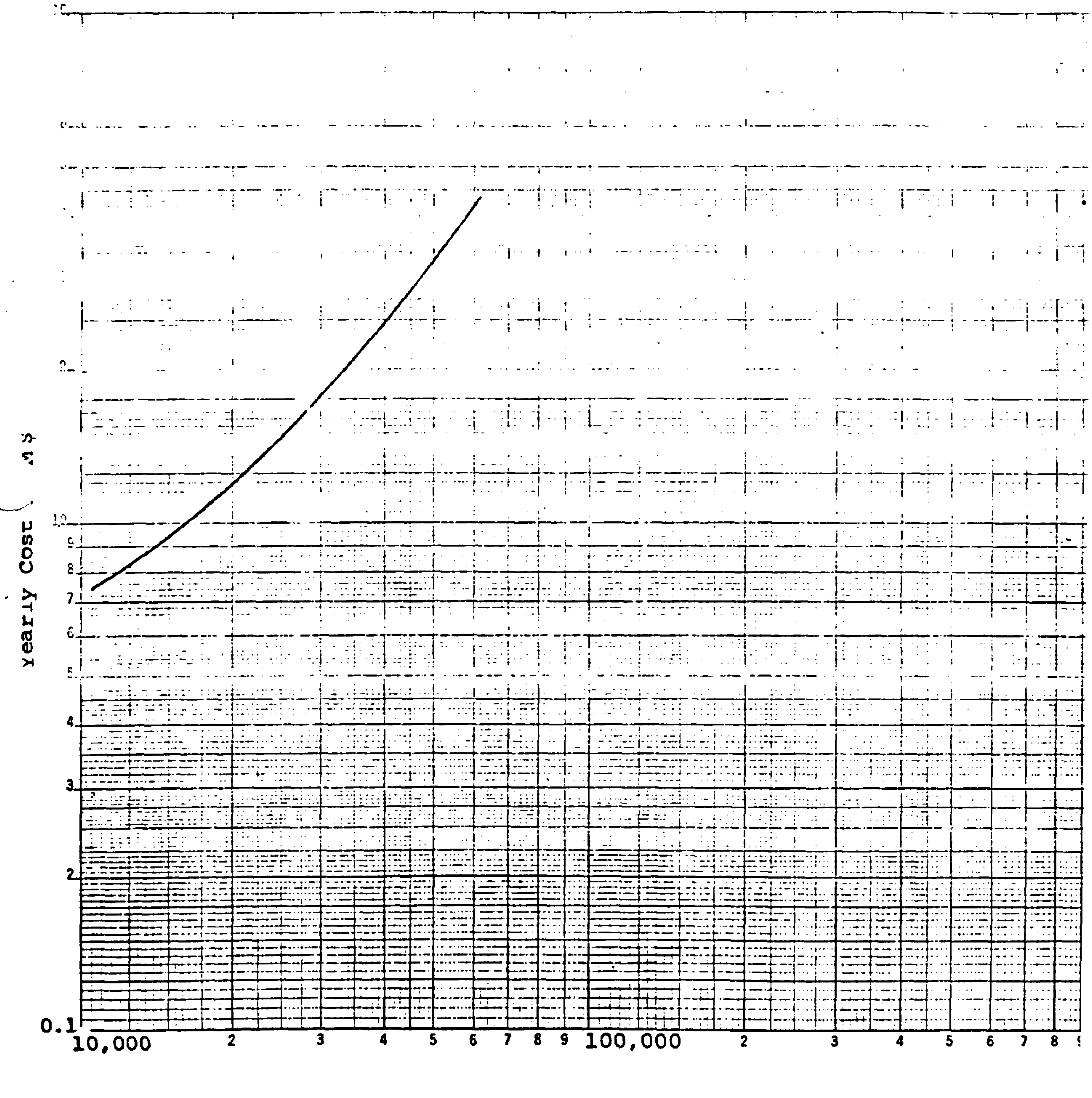
(see Figures 71 and 72). As the sensitivity plots show, there appears to be a very strong correlation between waste COD content and carbon treatment costs for the range covered.

Again, it must be emphasized that the capital costs described herein do not account for the added costs of foundations and supports, site preparation, outside battery limits piping and electrical, painting, general field costs, home office costs, contingencies, etc.

FIGURE 71

CASES 1 THROUGH 3

TOTAL YEARLY COST SENSITIVITY TO COD

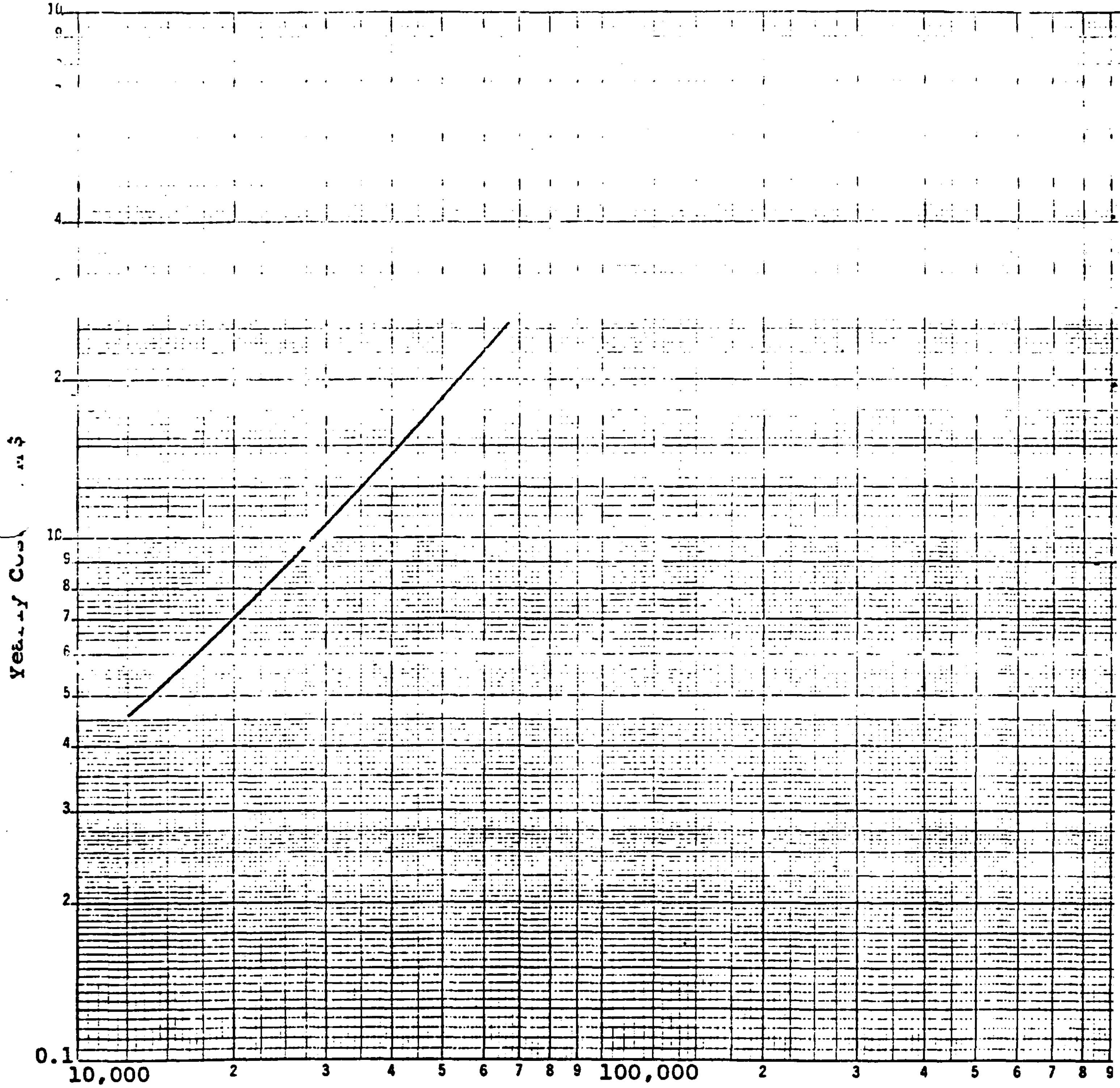


12-185

FIGURE 72

CASES 1A THROUGH 3A

TOTAL YEARLY COST SENSITIVITY TO COD



Logarithmic, 2 x 2 Cycles

FIGURE 44

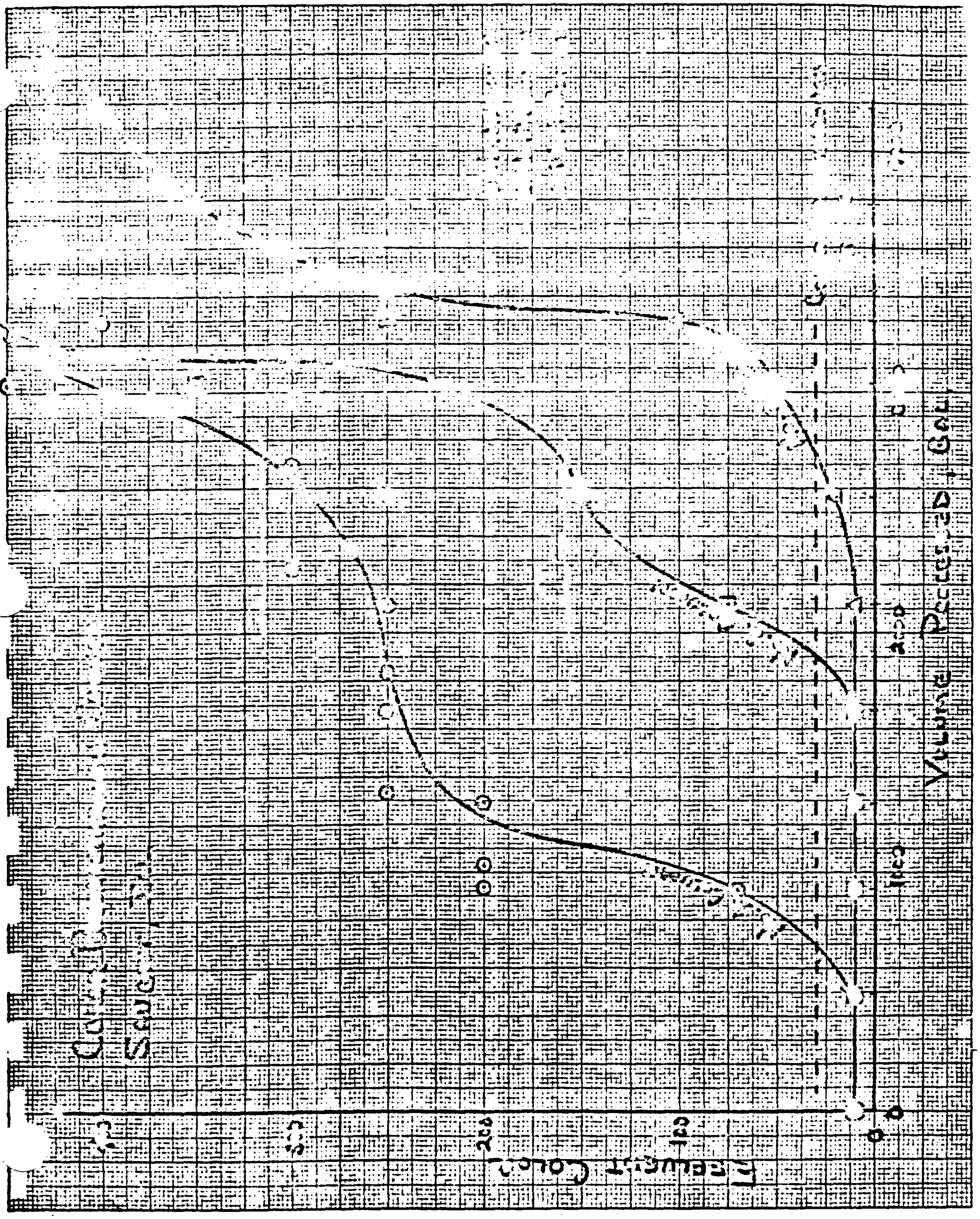
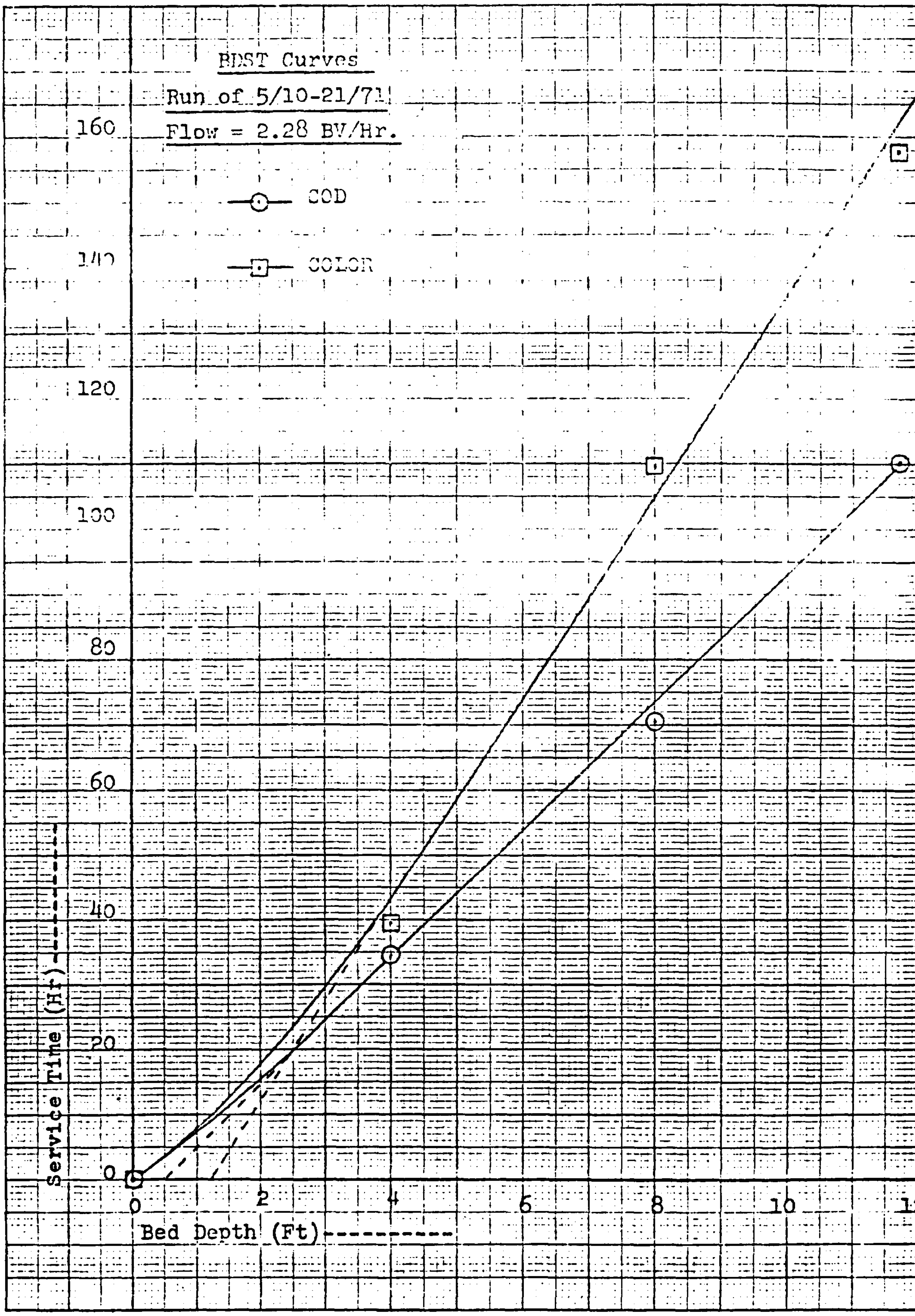
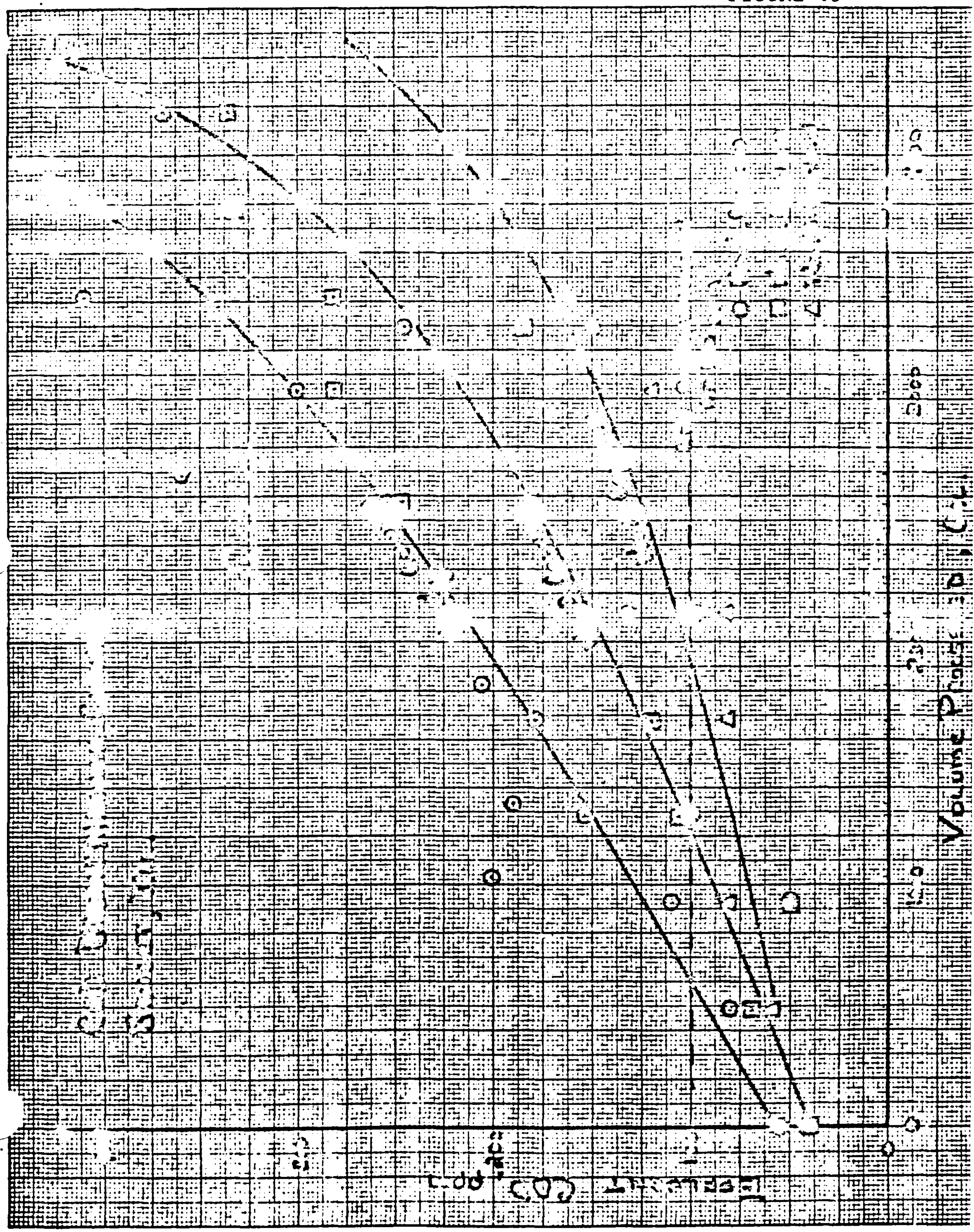


Figure 45



BDST Curves
Run of 5/10-21/71
Flow = 2.28 BV/Hr.
COD
COLOR
160
140
120
100
80
60
40
20
0
0
2
4
6
8
10
12
Service Time (Hr)
Bed Depth (Ft)

FIGURE 46



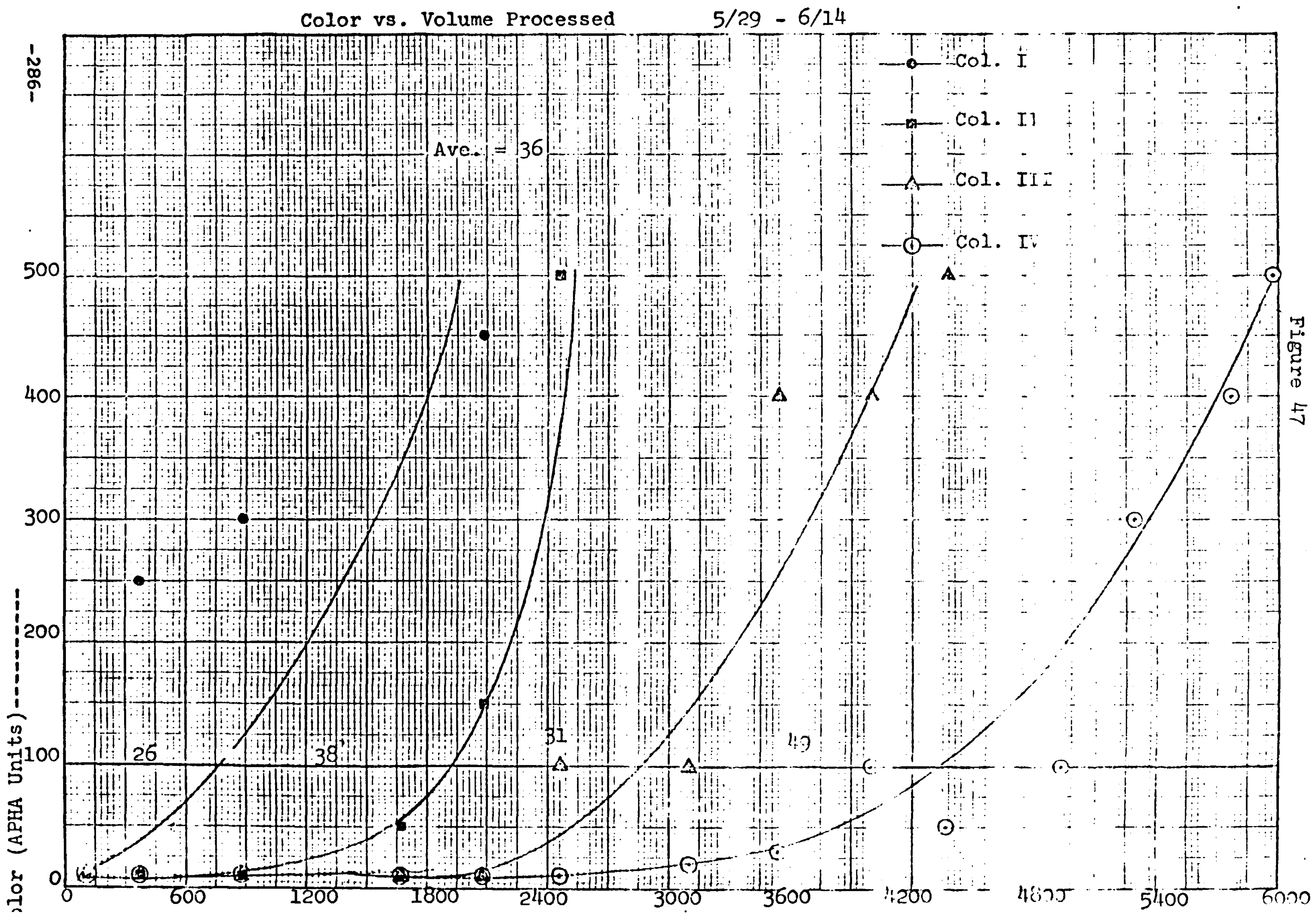

Color vs. Volume Processed
5/29 - 6/14
Col. I
Col. II
Col. III
Col. IV
Ave. = 36
26
38
31
49
Color (APHA Units)
0
100
200
300
400
500
0
600
1200
1800
2400
3000
3600
4200
4800
5400
6000

Figure 47

5/29 - 6/14 Run COD (mg/1) vs Gal. Processed

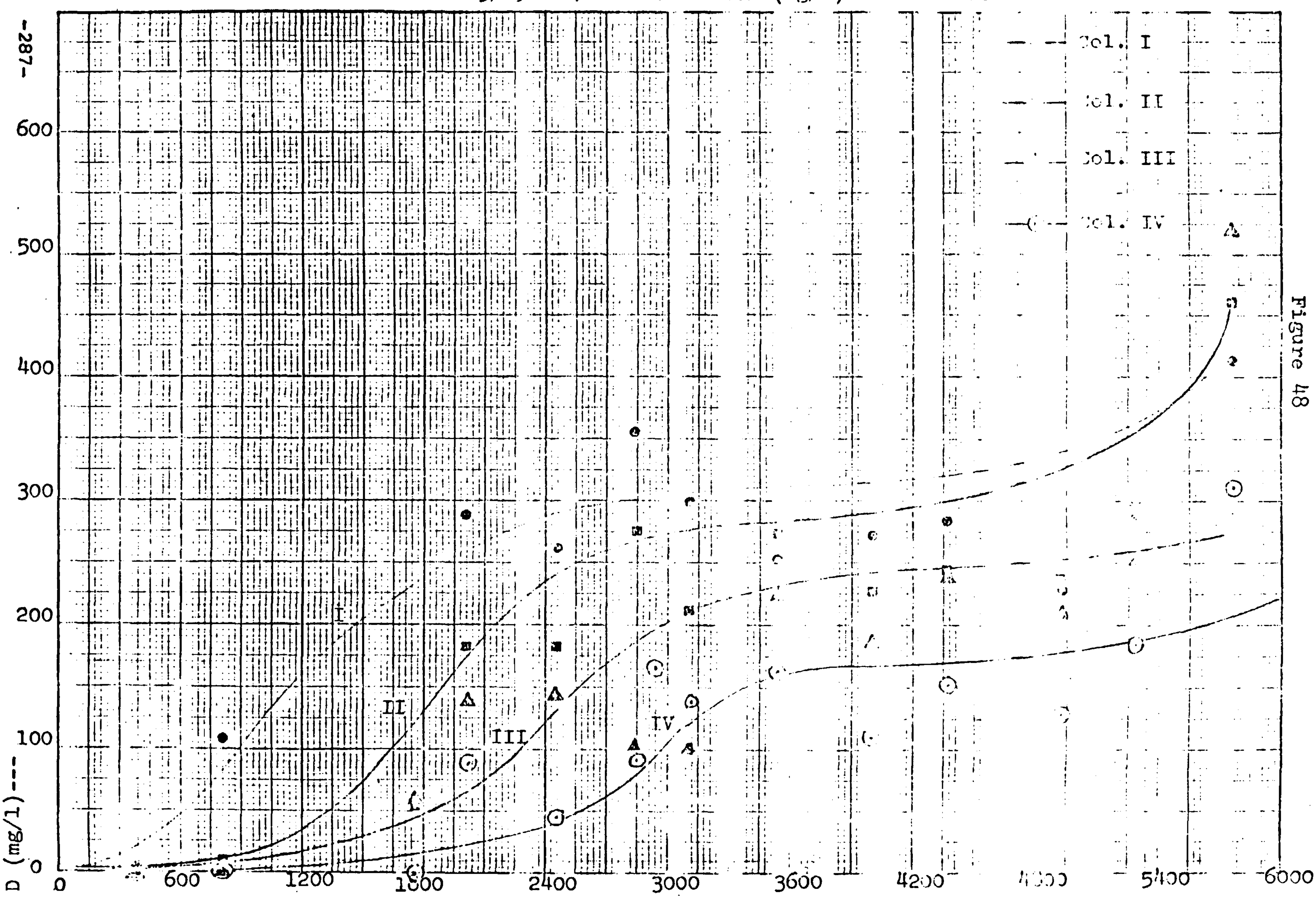
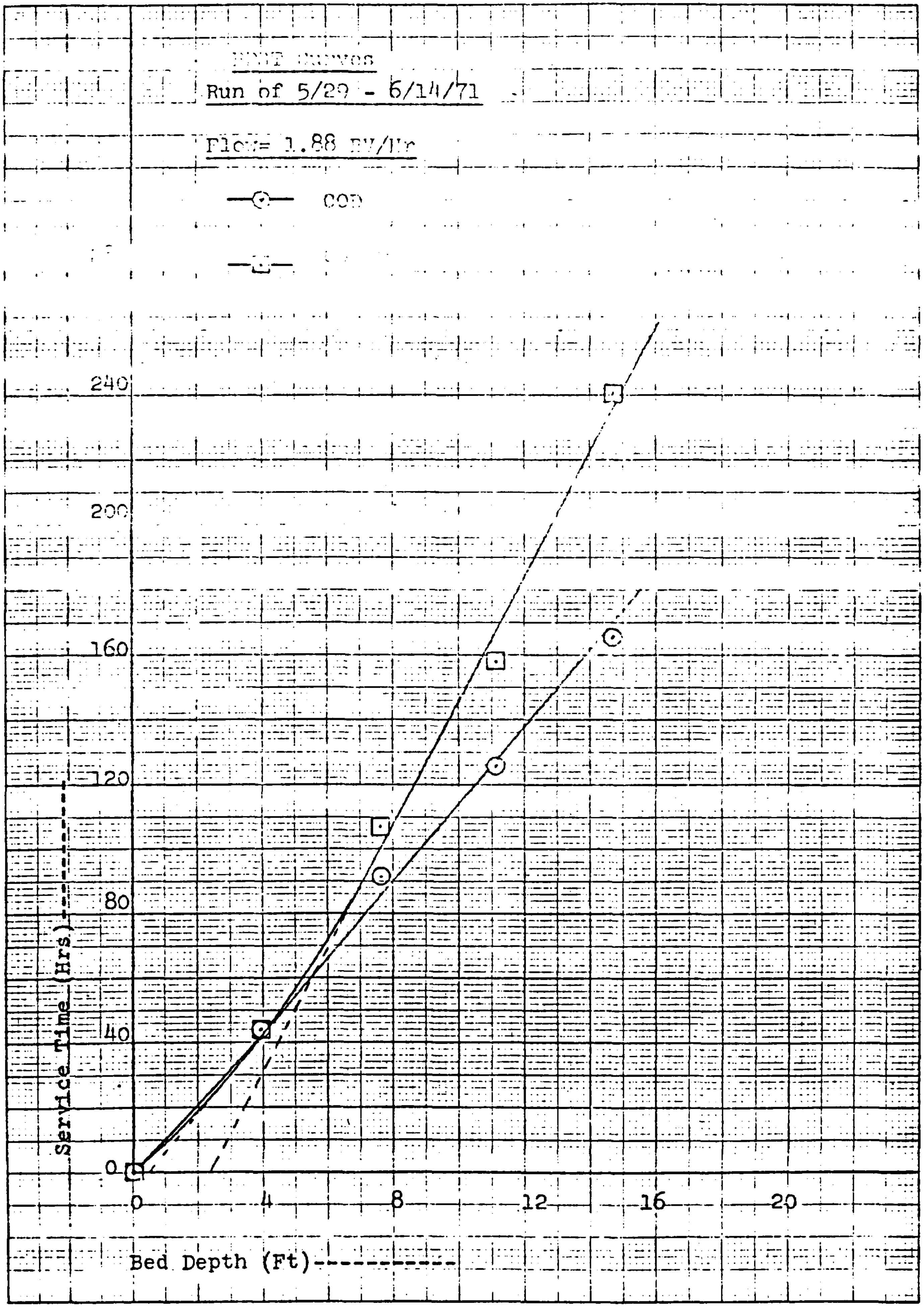


Figure 48

Figure 49



Run of 5/29 - 6/14/71
Flow= 1.88 BV/Hr
COD
240
200
160
120
80
40
0
0
4
8
12
16
20
Service Time (Hrs)
Bed Depth (Ft)

450 500 400

K+E 10 TO INCH 124
KEUFFEL & ESSER CO.

6/16 - 7/16 Color vs Volume Processed

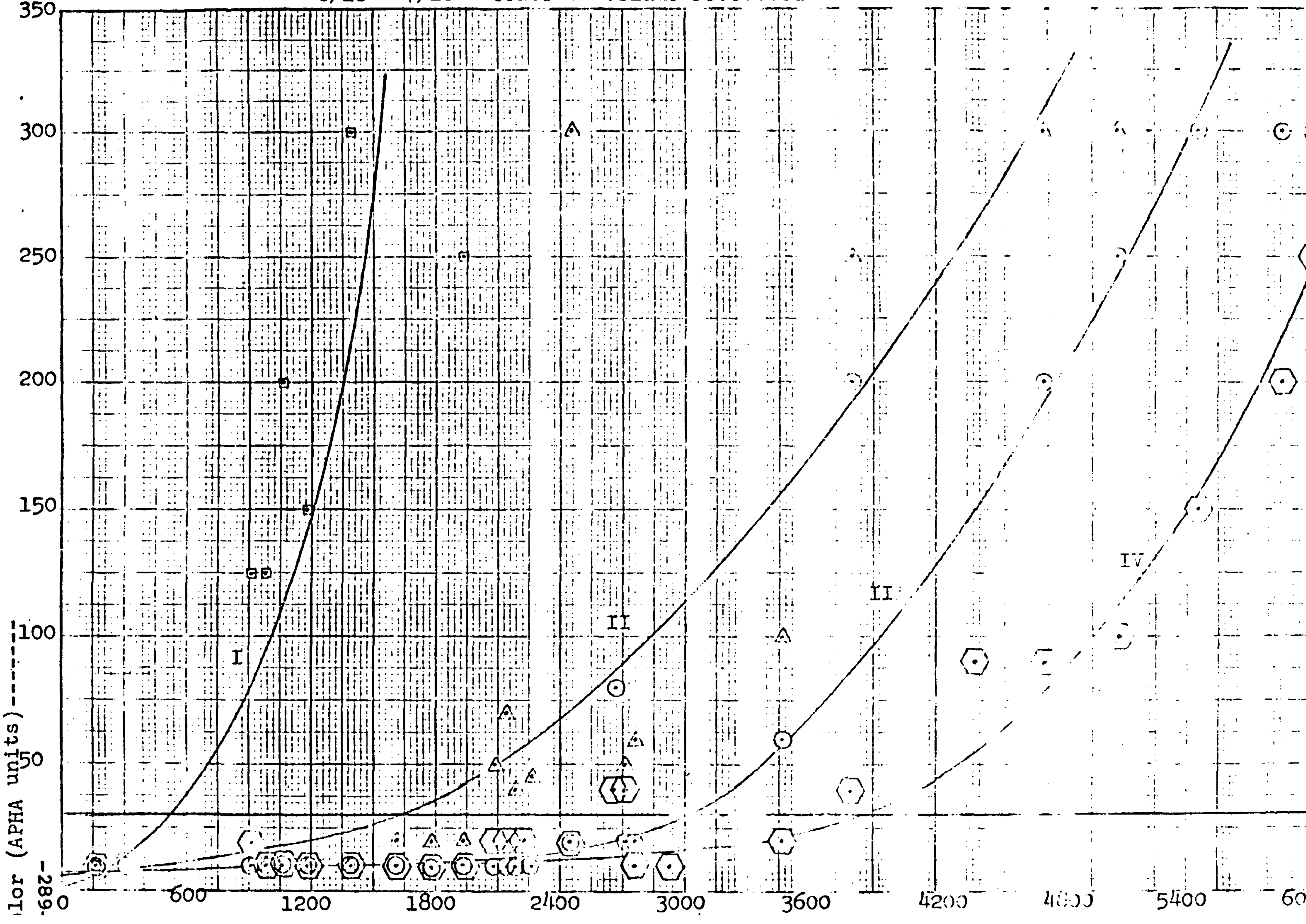


Figure 50

Figure 51

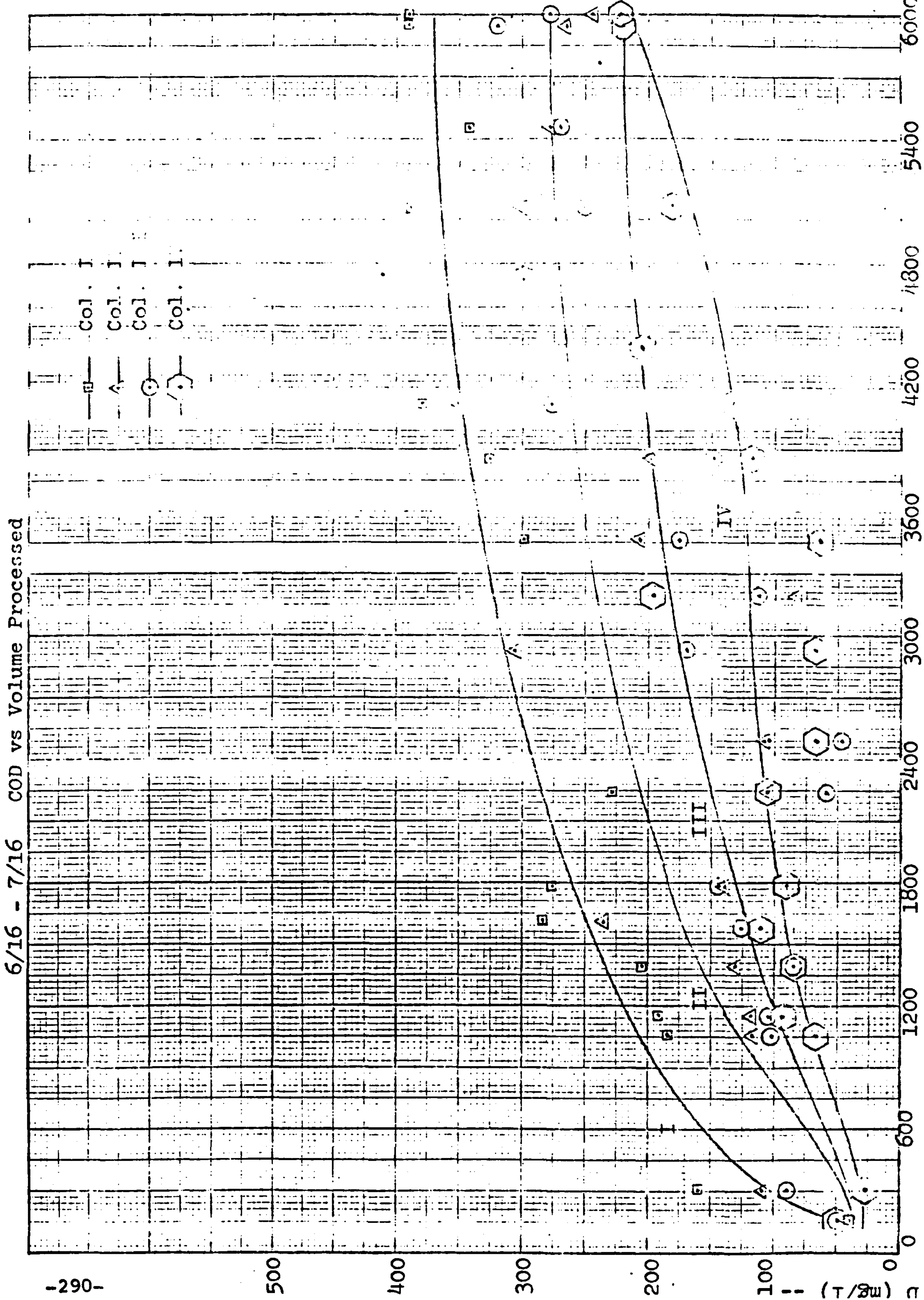
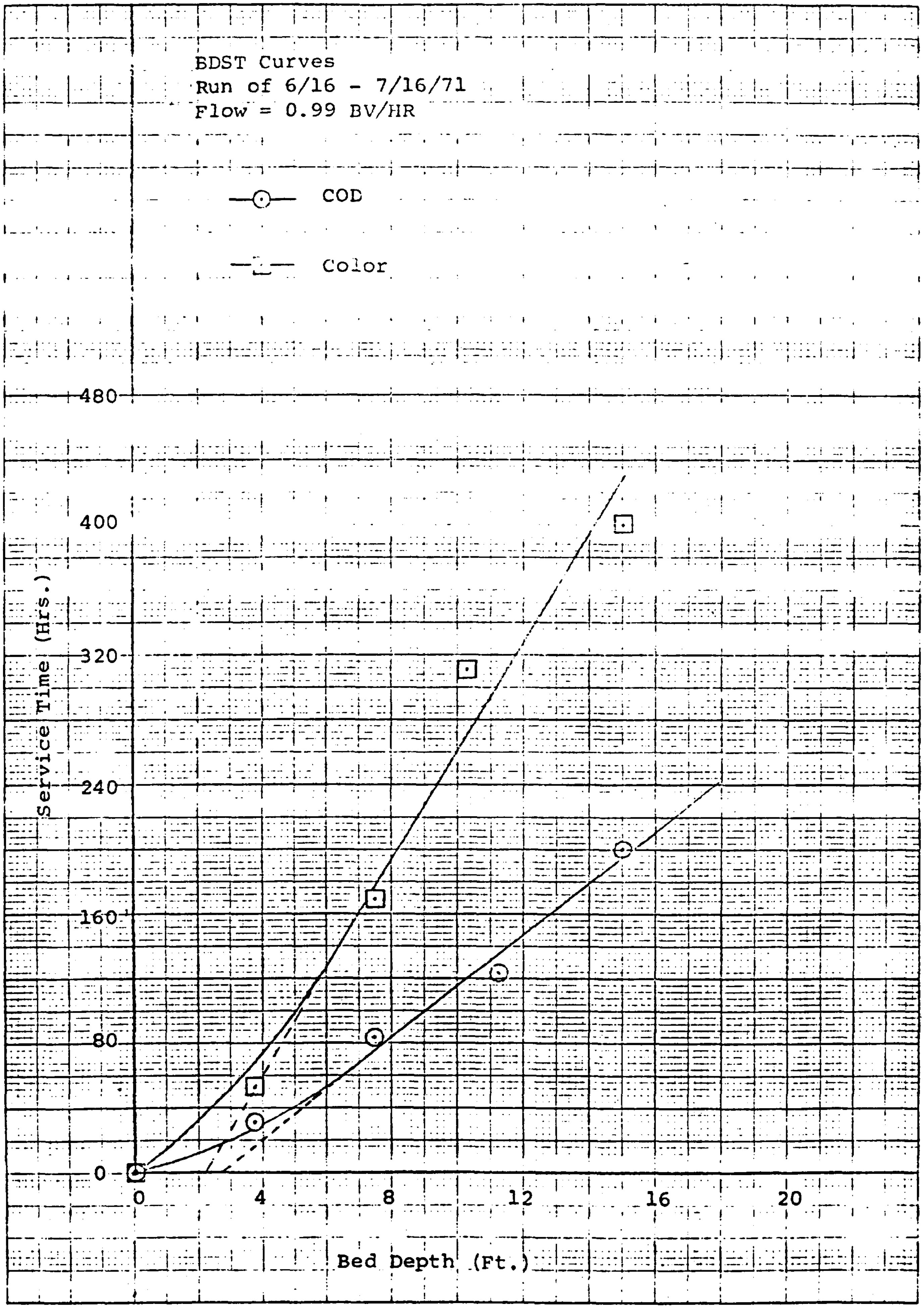

6/16 - 7/16 COD vs Volume Processed
Col. I
Col. I
Col. I
Col. I
II
III
IV
0
600
1200
1800
2400
3000
3600
4200
4800
5400
6000
0
100
200
300
400
500
(mg/l)

FIGURE 52


BDST Curves
Run of 6/16 - 7/16/71
Flow = 0.99 BV/HR
COD
Color
480
400
320
240
160
80
0
Service Time (Hrs.)
0
4
8
12
16
20
Bed Depth (Ft.)

Darco: Virgin vs Regenerated - Color vs Volume Processed

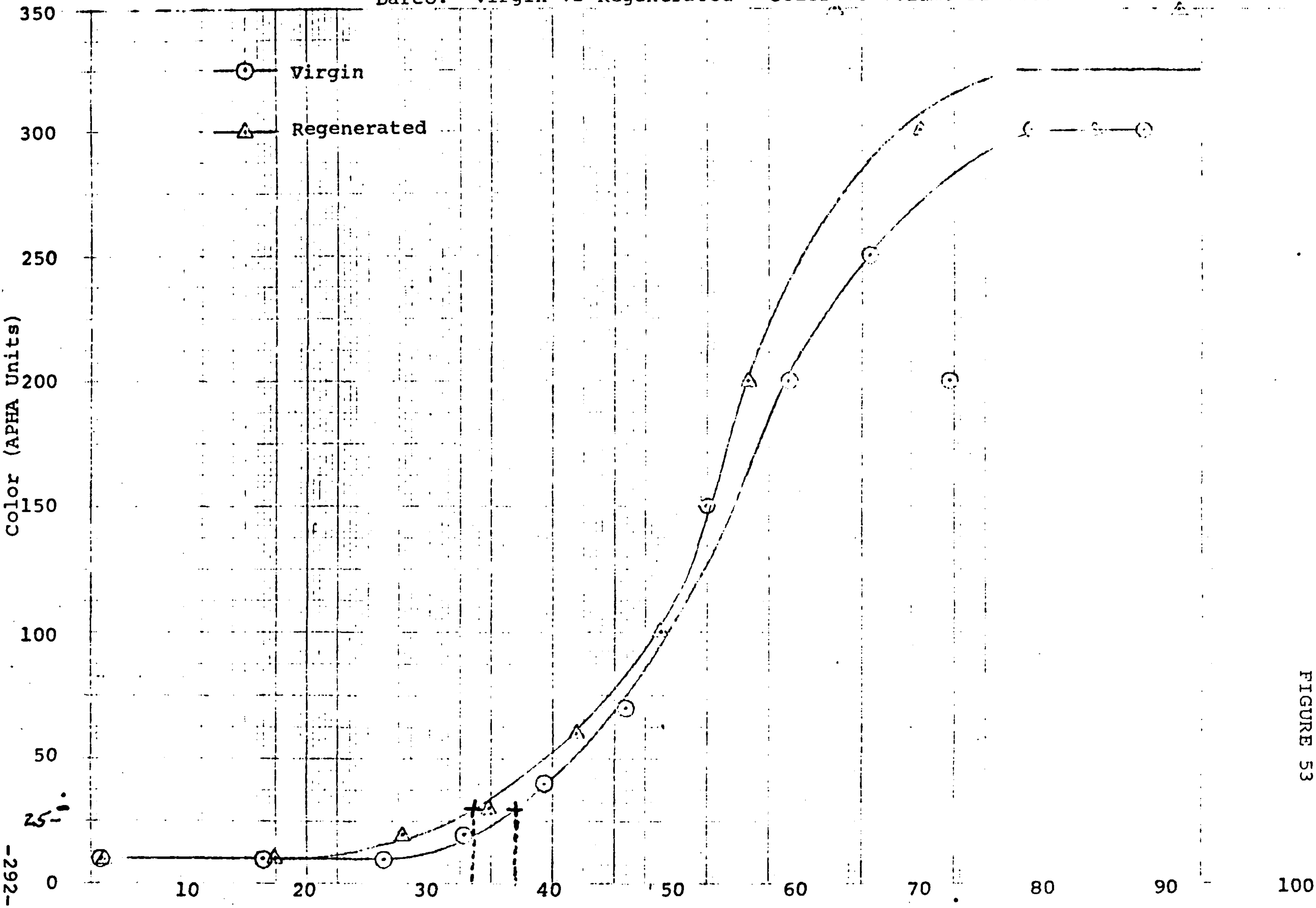
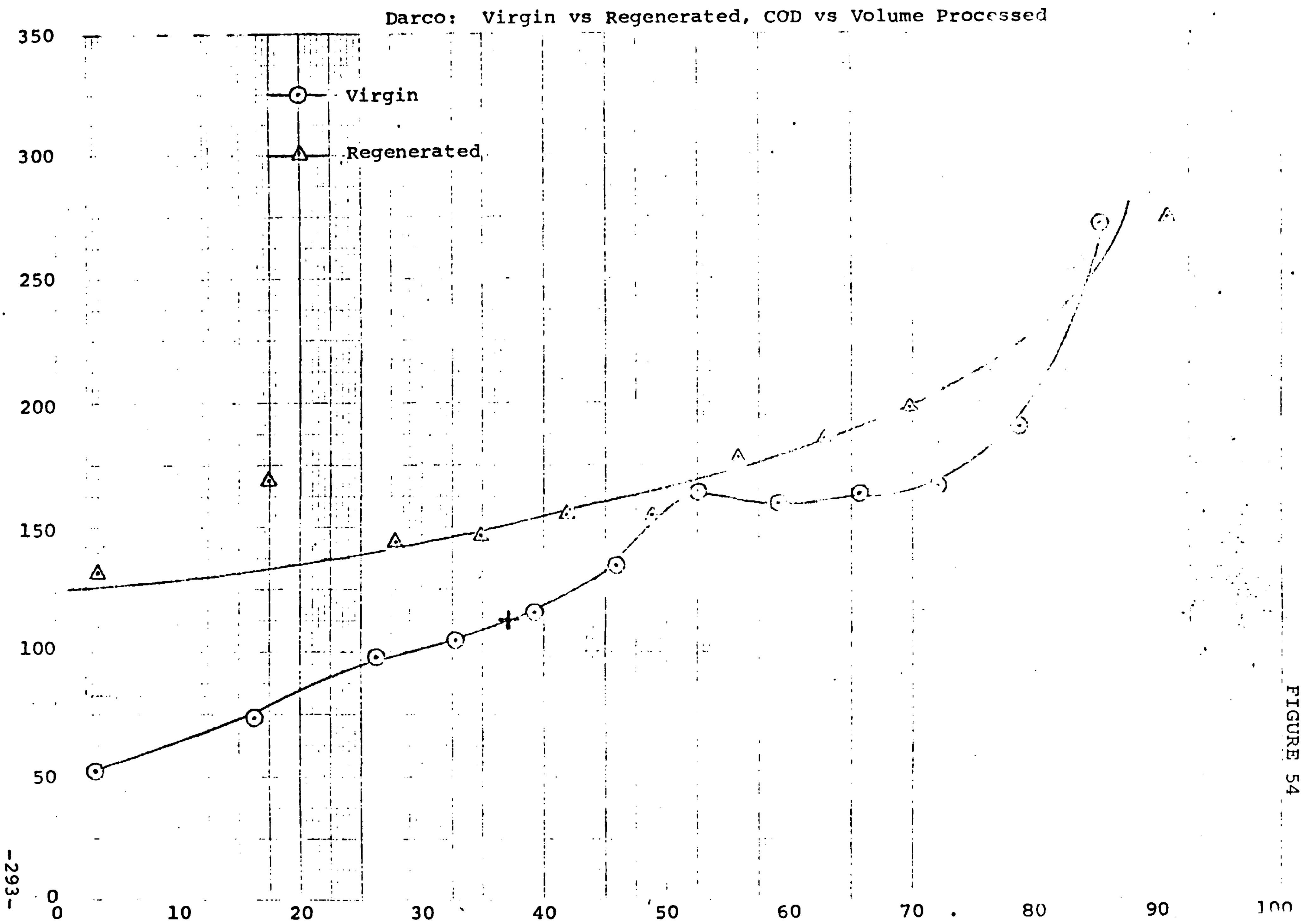


FIGURE 53



Darco: Virgin vs Regenerated, COD vs Volume Processed
Virgin
Regenerated
350
300
250
200
150
100
50
0
0
10
20
30
40
50
60
70
80
90
100

FIGURE 54